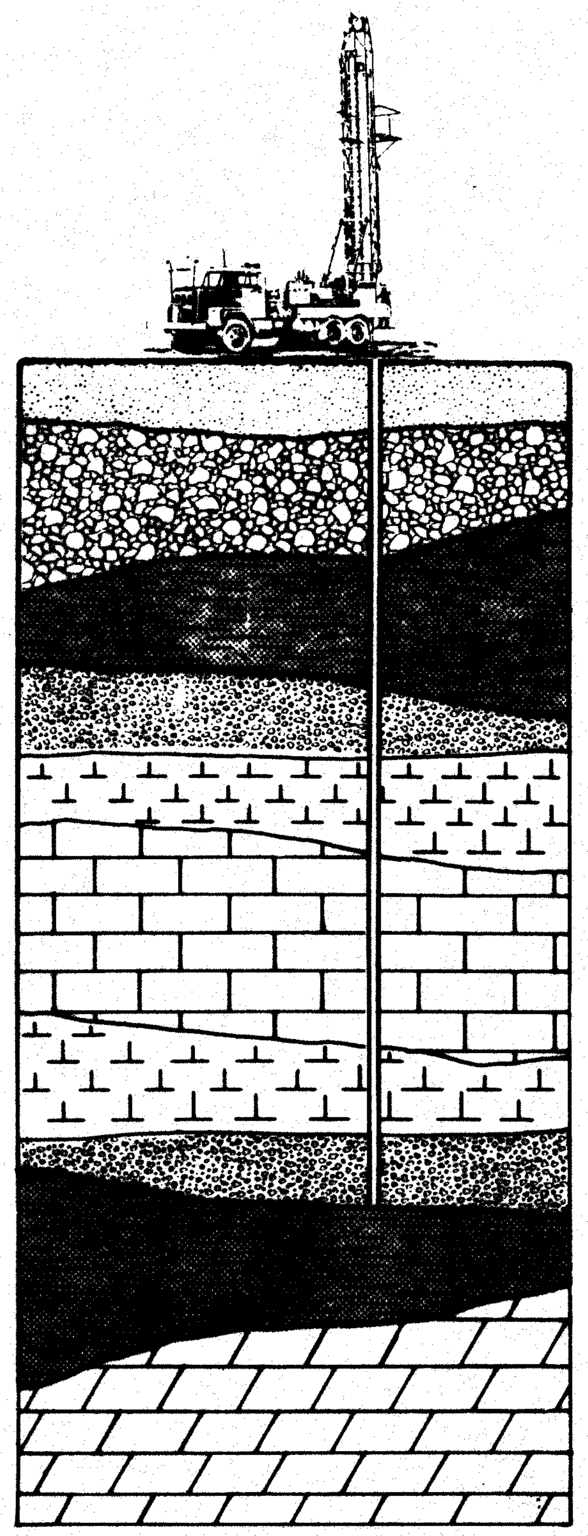
GROUNDWATER RESOURCES OF HANOVER COUNTY, VIRGINIA



by

Russell P. Ellison III

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PIEDMONT REGIONAL OFFICE

COMMONWEALTH OF VIRGINIA

STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

Richmond, Virginia

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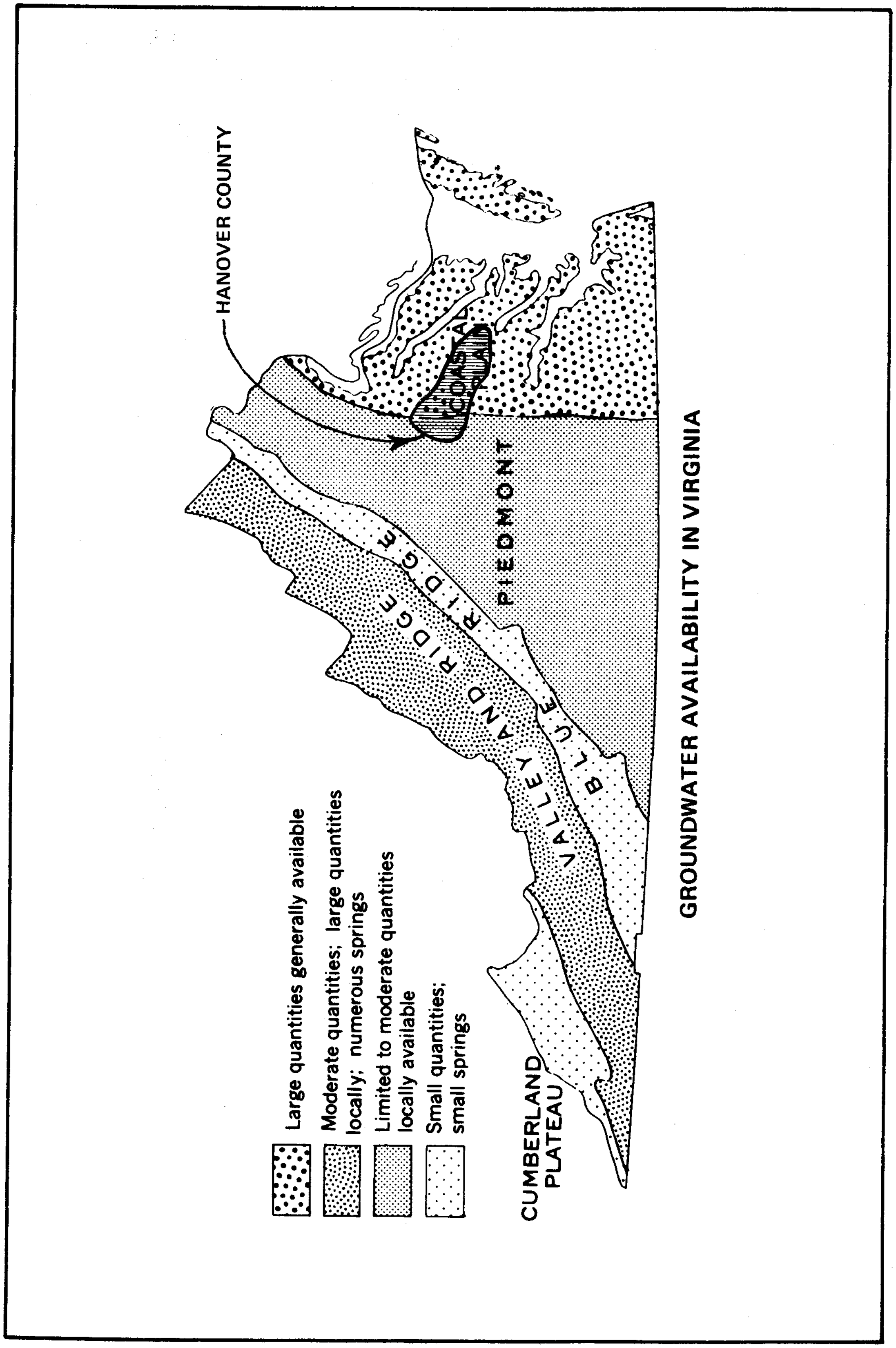

GROUNDWATER AVAILABILITY IN VIRGINIA

Source: Virginia State Water Control Board – BWCM

GROUNDWATER RESOURCES
OF
HANOVER COUNTY, VIRGINIA

by

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Virginia State Water Control Board
Bureau of Water Control Management
Richmond, Virginia

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The Office of Geology at the Piedmont Regional Office of the State Water Control Board is indebted to many individuals who made this Groundwater Report possible.

Most of our information was provided by the many helpful water well drillers who work in the Piedmont Region. The most informative of these drilling firms include Sydnor Hydrodynamics, Mitchell's Well and Pump Company, W. H. Gammon Well Drilling, and Matthews Well and Pump Company.

We wish to thank Rick Bower and Albert Giles for their comments on Hanover County's geology and geohydrology without which our ground water research work would have taken considerably longer. Craig Churn provided the computer expertise that produced the computer contour maps. Ed Adams and the Drafting and Reproduction Department provided the graphic skills that are so important in any formal publication.

We are grateful to all of these people for their diligence and help and especially to our typist, Paula Sexton, who tolerated the many revisions of this report.

FORWARD

The information contained in this report is a compilation of data from existing geologic reports, as well as original data collected by the staff of the Virginia State Water Control Board. Because of the scarcity of data over much of Hanover County, it became necessary to interpret and make some projections of the data. Where more detailed data existed, it was possible to use the information in its entirety. For this reason, certain portions of this report are more detailed than others.

This report also contains numerous computer contour maps which display static water level, yield, and chemical data. These maps were produced by computer from existing well data contained in the State Water Control Board's computer file. These data were derived from water well completion reports submitted by conscientious water well drillers, as well as from field studies done by the State Water Control Board and the State Department of Health. Regarding the areas of Hanover County for which little or no data had been collected, it was necessary to interpret and extrapolate information, so that a more complete County analysis could be presented. It should be recognized that other interpretations of the data are possible, but the conclusions herein offered are based on knowledge gained while working on this report and in the Region.

GROUNDWATER IN HANOVER COUNTY

ABSTRACT

by Russell P. Ellison, III

Groundwater in Hanover County provides the vast majority of the County's citizenry with a safe and reliable water supply. The true value of such a resource is incalculable, and under no circumstances should its natural purity be degraded or endangered. This report attempts to present a comprehensive view of this precious resource by discussing the geology-geohydrology, groundwater quality, recharge, storage, development, and present use throughout Hanover County.

The State Water Control Board's geology-geohydrology information has been correlated in an attempt to delineate the zones of highest groundwater yield and development potential. The information from the Piedmont section indicates that localized conditions determine the groundwater yield. The Piedmont's saprolite cover forms the shallow-low-yielding aquifer and the fractured bedrock comprises the deeper, higher yielding aquifer. The Fall Zone exhibits a mixture of both Piedmont and Coastal Plain geohydrologic characteristics. Existing records indicate that this zone yields inferior quality and quantities of groundwater (except along fracture and fault zones). In the Coastal Plain section, sedimentary formations contain the groundwater resource. The near-surface aquifers generally yield small quantities of groundwater. At depth, the upper artesian (Mattaponi/Nanjemoy Formations) and principal artesian (Patuxent Formation) acquifers are encountered. Due to the vast extent and thicknesses of these artesian aquifers, very high groundwater yields are noted. Piedmont-like basement complex rocks exist beneath the principal artesian aquifer. These basement complex rocks have water-bearing fractures and joints similar to the Piedmont rocks to the west. Of all of the aforementioned groundwater supplies, the Patuxent Formation (principal artesian aquifer) is and will remain the largest and most dependable source.

Groundwater quality is generally quite good throughout the County. Certain areas of the Fall Zone, Triassic basins, and some portions of the

artesian aquifers contain esthetically-unpleasant groundwater. High nitrate concentrations are recognized as a threat to many of the shallow aquifers. All major groundwater quality parameters are discussed and contoured by computer for accurate delineation within the County. The available data substantiates that groundwater quality is generally good, but that considerable planning and care should be taken to protect it for the future.

Values for groundwater recharge and storage of the Coastal Plain Patuxent Formation (principal artesian aquifer) are provided in order that future development and use may be planned for in an equitable and conscientious manner. Presently, it is estimated that groundwater supplies in the County far exceed the demand. Future population increases and associated development and use will necessitate a closer analysis of recharge and storage capacities of the major aquifers.

CHAPTER I

INTRODUCTION

Purpose and Scope

This report is designed to acquaint the public with the latest information on the location, quality and quantity, and future potential of Hanover County's groundwater resources. It is intended to be an aid to the private citizen, government agencies, developers, county planners, well drilling contractors, and all others interested in the location, development, utilization, and protection of the groundwater of Hanover County.

Much basic information, as well as detailed scientific data, have been combined in this report in order that the layman, as well as the professional can be assisted.

Introduction

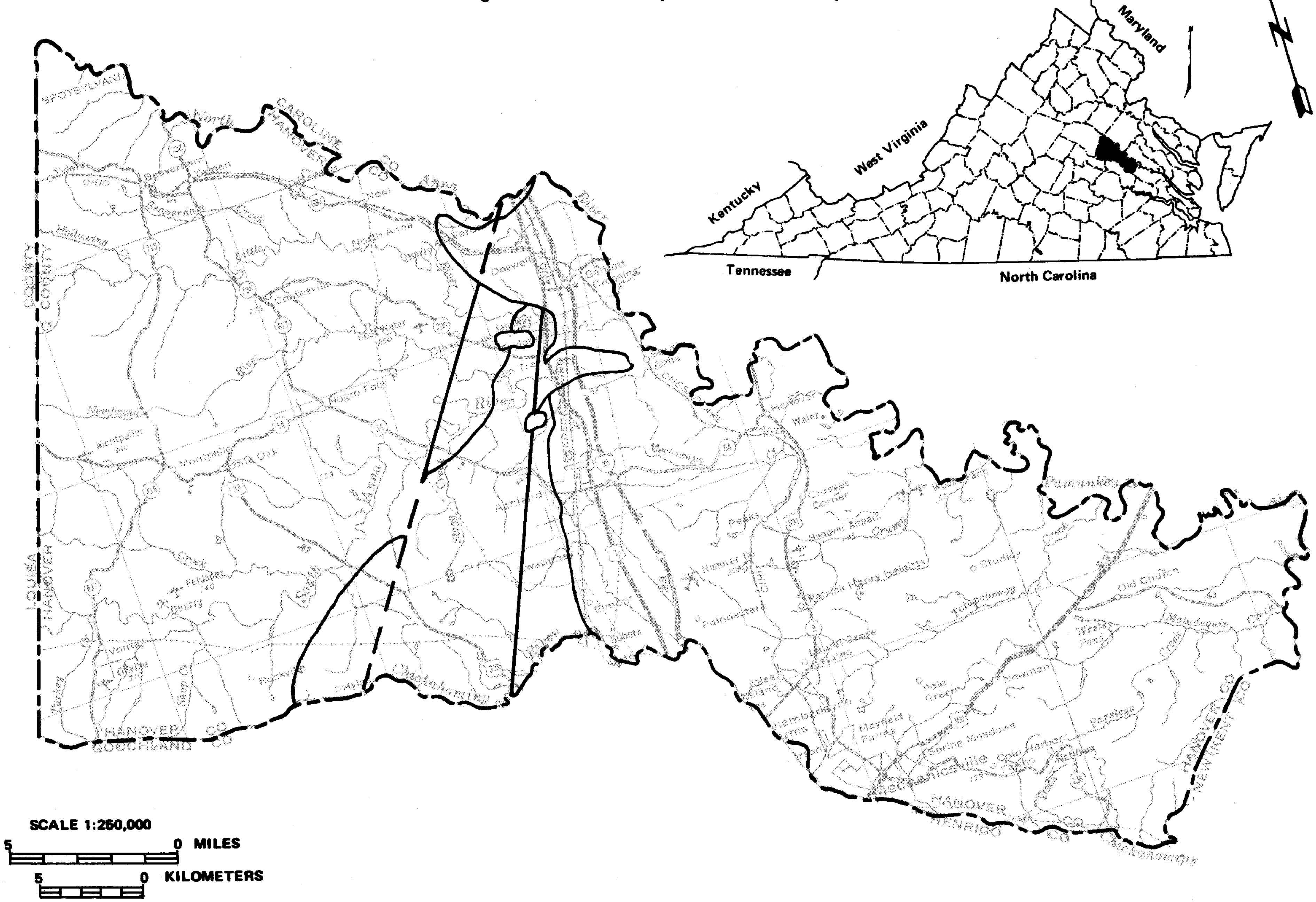
Hanover County was formed in 1720 from a portion of New Kent County and named for the Duke of Hanover. The County seat is at Hanover Courthouse which was established in 1735. The land area of the County totals approximately 466 square miles (298,240 acres) with five square miles (3200 acres) of inland water.

The County is located in east-central Virginia and is bounded on the north by Spotsylvania, Caroline, and King William Counties; on the east by New Kent County; on the south by Henrico and Goochland Counties; and on the west by Louisa County (Figure 1).

The North Anna and Pamunkey Rivers form the northern boundary, with the Chickahominy River lying along the eastern part of the southern boundary. The South Anna River, Taylor's Creek, New Found River, Little River, and Totopotomoy Creek are the major streams which traverse the County.

The total population of the County in 1972 was 41,000. The population projections by the Division of Intergovernmental Affairs for the year 1980 are over 60,000, and for the year 2000 the estimate is

Figure 1. Location map of Hanover County.



SOURCE: STATE WATER CONTROL BOARD – PRO

108,000. The Town of Ashland is the only incorporated town in the County, with a 1970 population of 2,934 and present (1978) estimates of over 6,100.

Method of Investigation and Data Assembly

The background information for this report was acquired from previous regional and State reports and from the latest data published by Hanover County. Much of the census and economic data were collected from County officials and other State agencies.

Information on the climate, soils, and vegetation came from specialized county and regional reports. Surface water (runoff and drainage) information was supplied by the State Water Control Board.

The pertinent geology and geohydrologic data were collected by the State Water Control Board's Bureau of Water Control Management and the Piedmont Regional Office. The Groundwater Act of 1973 has provided for such data collection in that it requires a Water Well Completion Report (Form GW-2) to be submitted within 30 days to the Board for each newly constructed water well (Appendix 1). This Water Well Completion Report requires that the location, owner, contractor, basic well construction data, screen locations, pump data, and driller's logs be recorded. Geophysical logs are not required but are a great aid in geohydrologic interpretation. Each Water Well Completion Report must be accompanied by well cuttings collected for each 10 feet of depth drilled unless previous exemption is secured from the State Water Control Board. Sample bags for the cuttings are provided free by the Bureau of Water Control Management in Richmond. Also, all industrial and public supply water well users are required to submit a Groundwater Pumpage and Use Report (Form GW-6) to the Board quarterly (Appendix 1).

For better data management and groundwater protection, the State Water Control Board requires that all wells no longer in use be temporarily or permanently abandoned. When an industrial or public water supply water well is to be abandoned, the owner must submit an Application and Report - Abandonment of Water Well (GW-5) prior to the initiation of the abandonment procedures (Appendix 1). The Board requires that this form be filed to certify that pumping and use of groundwater from that well has been stopped and to insure that all industrial and public supply wells are sealed properly to prevent groundwater contamination by other groundwater, surface waters, and pollutants.

Groundwater Quality information is collected weekly by the Piedmont Regional Office. One of the twenty-two counties in the region is sampled randomly each week. The groundwater quality samples come from wells with completion reports on record at the Piedmont Regional Office. Chemical analyses for twenty-eight groundwater quality parameters are performed by the State of Virginia Consolidated Labs.

Groundwater Quality information also is acquired through the Pollution Response Program (PReP). This program responds to citizen's complaints of groundwater and surface-water pollution. Hazardous chemicals, oil, gasoline, refuse, siltation, sewage, and industrial wastes are some of the pollutants that frequently endanger the quality of groundwater.

The central repository for all Hanover County well information, water well completion reports, and groundwater quality records is the State Water Control Board Headquarters Office in Richmond. Copies of this information are on file at the Piedmont Regional Office. The information has also been recorded on computer and is made available on the interested public.

Previous Investigations

Geologic information on portions of Hanover County is available from the Virginia Division of Mineral Resources (VDMR) in Charlottesville. The geology of the Piedmont section (west of the Fall Zone) of Hanover County lacks 7½' quadrangle scale mapping except for that which has been partially interpreted by Bruce K. Goodwin in the Geology of the Hylas and Midlothian Quadrangles, Virginia: VDMR, RI. 23 (1970). The remaining Piedmont geologic delineation was inferred regionally from D. J. Cederstrom, Geology and Groundwater Resources of the York-James Peninsula, Virginia, U. S. Geologic Survey Water Supply Paper 1361 (1957).

The most recent geologic information on the Coastal Plain of Hanover County was published by Paul A. Daniels, Jr., and Emil Onuschak, Jr. on the Geology of Studley, Yellow Tavern, Richmond, and Seven Pines Quadrangles, Virginia: VDMR, RI. 38 (1974). This work, in the U. S. Geological Survey 7.5 minute scale, interprets only four of the eight Coastal Plain quadrangles in Hanover County; therefore, many of the characteristics of Coastal Plain Geology (east of the Fall Zone) were interpreted from these quadrangles. The geology of the remaining areas of the Coastal Plain has been obtained from R. H. Teifke and Emil Onuschak, Jr. Geologic Studies, Coastal Plain of Virginia: VDMR, Bulletin 83 (1973).

Geohydrologic information is extremely limited for the entire County and was inferred from both regional reports and State Water Control Board data. Geohydrologic studies do not exist for the Piedmont section. Consequently, this data must be determined solely from the State Water Control Board's water well information. In the Coastal Plain, the geohydrology is partially defined by D. J. Cederstrom, Geology and Groundwater Resources of the York-James Peninsula, Virginia, (1957); E. A. Siudyla, T. D. Berglund, and V. P. Newton, Groundwater of the Middle Peninsula, Virginia [SWCB Planning Bulletin 305 (1977)]; and Virginia Division of Water Resources, Groundwater, Henrico County, Virginia [Preliminary Basic Data Bulletin 36P (1971)].

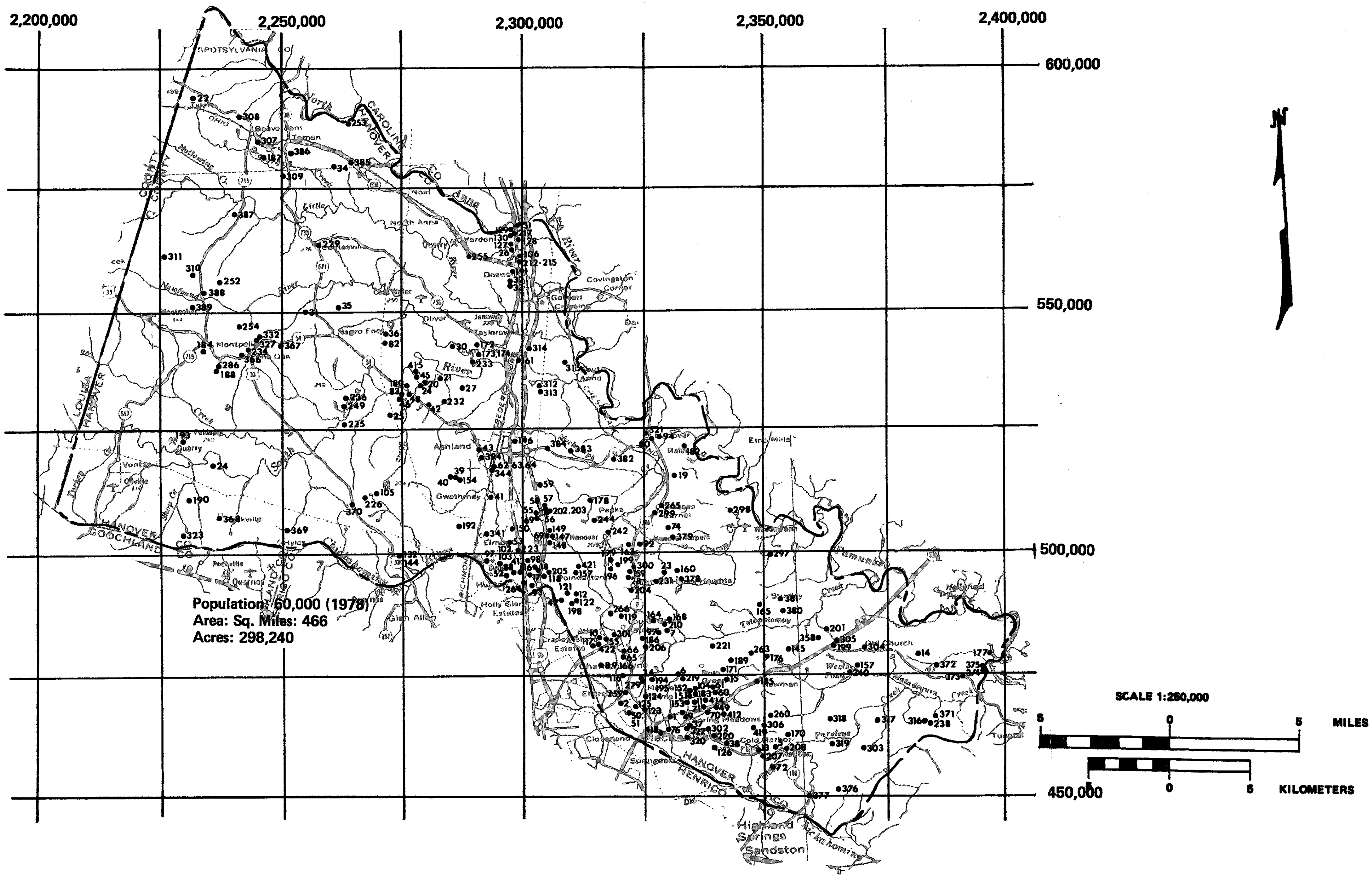
Water Well Numbering System

Each water well completion report acquired by the State Water Control Board receives a specific number. The first three digits refer to the particular county in which the well is located. These first digits run from 100 to 237 with those from 100 to 199 representing, in alphabetical order, the counties in Virginia; numbers from 200 to 237 represent cities and incorporated towns. The remaining digits in the completion report number are for the particular well in the county, city, or town. For example, well number 142-318 represents Hanover County (142), and this is the 318th recorded well in that county.

All of the information about a particular well acquires the same number. This includes water quality, groundwater pumpage and use, geophysical logs, and geologic logs. All of the wells are listed in numerical order and most in chronological order. Both the Board's files and the computer printout are based on this numbering system. When it is necessary to contact the Board about a particular well, it is advisable to refer to the well number, the owner, its location, and the date of construction. This information will allow for more efficient assistance in well data retrieval.

All wells which have heretofore been located in Hanover County are shown in Figure 2. Detailed data on each well is included in Appendix 2.

FIGURE 2. WELL LOCATIONS IN HANOVER COUNTY.



Source: U. S. Geologic Survey; State Water Control Board – P.R.O.

CHAPTER II

PHYSICAL SETTING

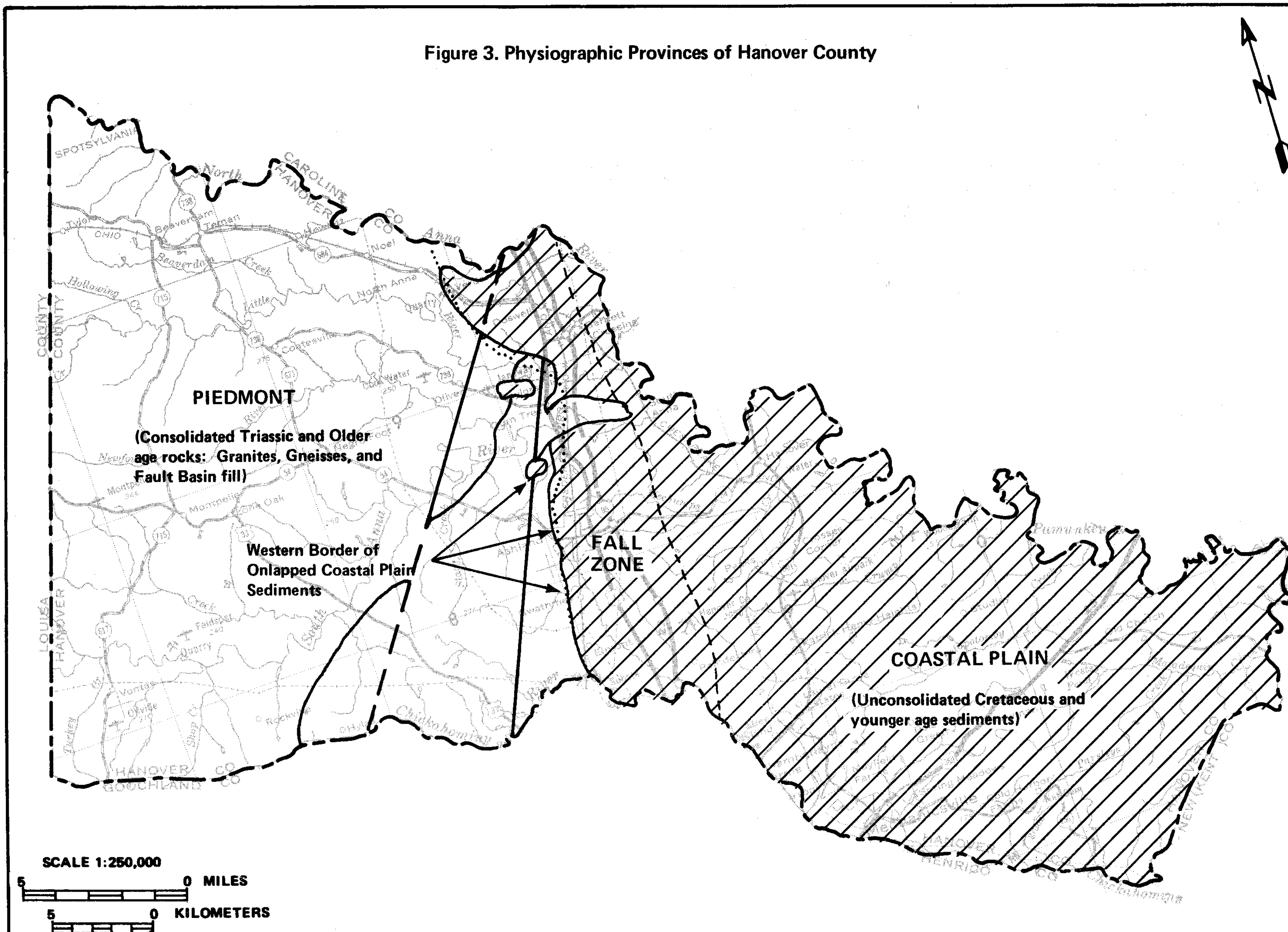
Physiography, Land Use, and Surface Hydrology

Hanover County is located in both the Piedmont and Coastal Plain Physiographic Provinces of Virginia (Figure 3). The western portion of Hanover County lies in the Piedmont Province. This province is characterized by gently rolling hills which are predominantly composed of igneous and metamorphic rocks such as granite, gneiss, and schist. The hills are separated by moderately well-incised streams which drain in an eastward direction. Elevations above mean sea level (msl) in the Piedmont portion of Hanover County range from about 100 feet (30 meters) in easternmost drainageways to slightly above 300 feet (91 meters) on the highest western knolls.

The eastern portion of the County lies in the Coastal Plain Province. It is composed of unconsolidated sediments such as clay, sand, and gravel. The elevations in the Coastal Plain section are lower than those seen in the Piedmont portion, with elevations slightly above 200 feet (61 meters) msl on the western hills of the Coastal Plain Province, to below 100 feet (30 meters) msl in drainageways toward the east. The Coastal Plain streams, unlike the Piedmont streams, have a lower gradient of flow due to the almost-level topography. Along with the low gradient the non-confining properties of both the topography and unconsolidated sediments enable the streams in the Coastal Plain to meander (as exemplified by the Pamunkey River).

The two Provinces are separated by the Fall Zone which extends in a north-south direction through the central portion of the County. This Zone is defined as the area in which the contact between Coastal Plain sediments and the basement Piedmont crystalline rock exists. Stream velocities in this area change abruptly from a rapid rate of flow, as the streams pass over the crystalline rocks, to a slower rate of flow as the streams pass over the Coastal Plain sediments.

Figure 3. Physiographic Provinces of Hanover County



SOURCE: STATE WATER CONTROL BOARD – PRO

Land use in the County is predominately agricultural. Approximately 87 square miles is cropland, with pastures comprising about 27 square miles and forests occupying 257 square miles. Urban areas account for about 10 square miles.

The County is located in both the York (Sub-basin II) and James (Sub-basin II) River Basins. Drainage is eastward toward the Chesapeake Bay with the Chickahominy, South Anna, North Anna, Pamunkey, Little, and New Found Rivers being the major drainageways.

Climate and Soils

The climate is temperate in Hanover County with cold, but not severe winters and moderately warm summers. Average daily winter temperatures range from 29°F to 48°F (-2°C to 9°C); average daily summer temperatures range from 67°F to 88°F (19°C to 31°C). Precipitation ranges from 42 to 46 inches (1.07 to 1.17 meters) per year. Droughts and flooding are fairly common in Hanover County, with the major floods caused by hurricane activity. Temperature and precipitation data are given in Table 1.

The soils of Hanover County have been described adequately in Report 17 from the Extension Division of Virginia Polytechnic Institute and State University entitled, Soils of Hanover County Virginia.

The county has been surveyed, and in general, some 70 different soils have been identified in Hanover County. These soils are derived from the indigenous parent rocks and, consequently, show differences between the two Provinces. Figure 4 is a reproduction of the generalized soil map of Hanover County and contains the soil descriptions and associations.

Table 1. Average Temperature and Precipitation Data for Hanover County from 1962 - 1973.

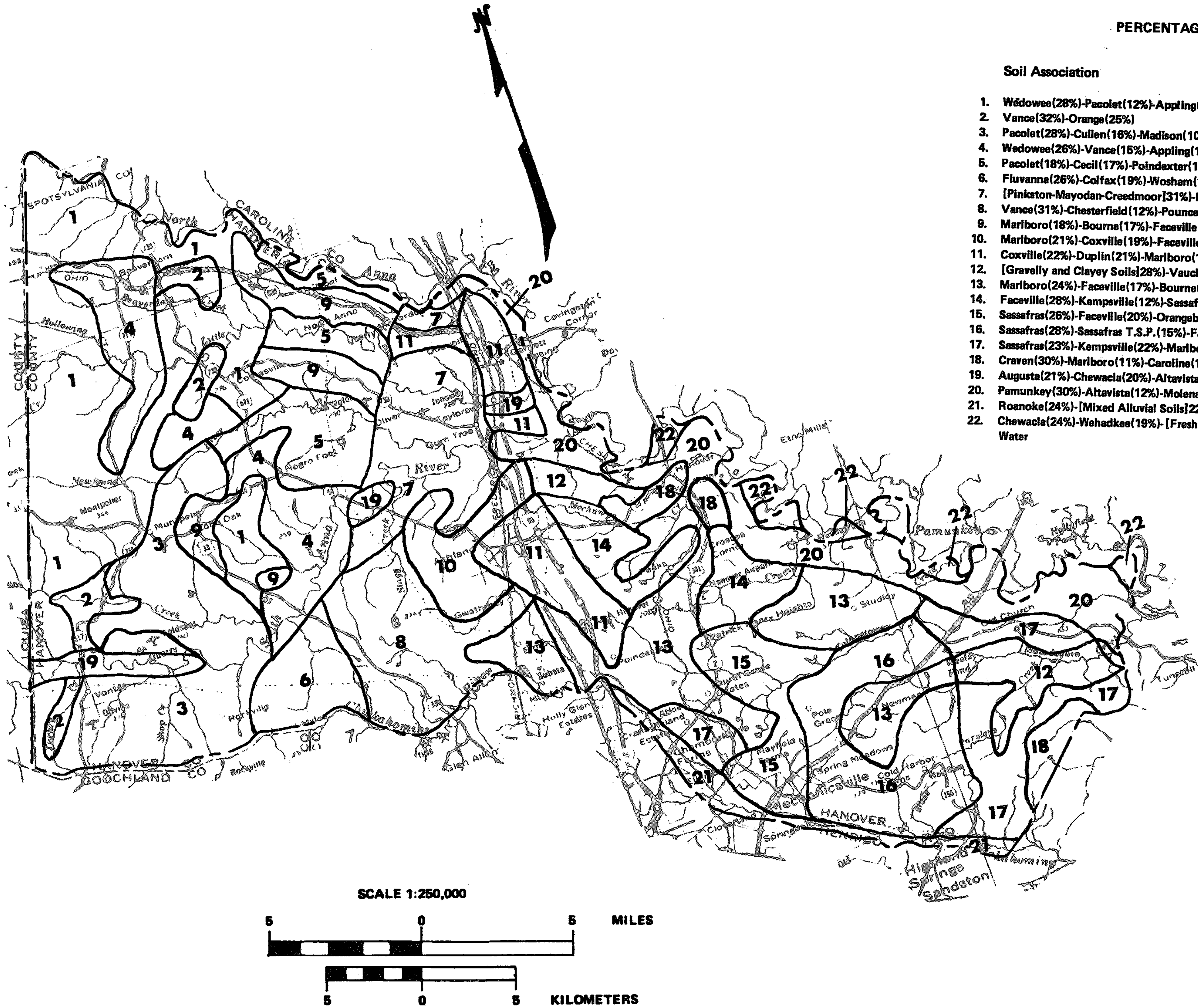
1962 - 1971	January	July	Annual
Temperature ^{o}F (^{o}C)	37.8^{o} (3.2^{o})	77.7^{o} (25.4^{o})	57.6^{o} (14.2^{o})
Precipitation inches (meters)	2.83 (0.072m)	5.78 (0.147m)	43.09 (1.094m)

Temperature Extremes ^{o}F (^{o}C) - Selected Years

Year	High	Low	Annual Average
1960	99 (37.2)	10 (-12.2)	55.6 (13.1)
1963	96 (35.6)	7 (-13.9)	56.1 (13.4)
1967	94 (34.4)	3 (-16.1)	56.2 (13.4)
1970	100 (37.8)	-1 (-18.3)	58.1 (14.5)
1971	93 (33.9)	3 (-16.1)	57.9 (14.4)
1973	96 (35.6)	6 (-14.4)	57.9 (14.4)

Source: Soils of Hanover County, Virginia, p. 3.

FIGURE 4. SOIL ASSOCIATION MAP, HANOVER COUNTY, VIRGINIA.



PERCENTAGES AND ACREAGES OF SOIL ASSOCIATIONS

	Soil Association	Total Acres	% of County
1.	Wedowee(28%)-Pacolet(12%)-Appling(11%)	42,764	14.2
2.	Vance(32%)-Orange(25%)	7,038	2.5
3.	Pacolet(28%)-Cullen(16%)-Madison(10%)	28,098	9.3
4.	Wedowee(26%)-Vance(15%)-Appling(14%)	18,202	6.1
5.	Pacolet(18%)-Cecil(17%)-Poindexter(15%)	12,886	4.3
6.	Fluvanna(26%)-Colfax(19%)-Wosham(10%)	7,246	2.4
7.	[Pinkston-Mayodan-Creedmoor(31%)-Bourne(13%)-Marlboro(10%)	13,786	4.5
8.	Vance(31%)-Chesterfield(12%)-Pouncey(10%)	14,670	4.9
9.	Marlboro(18%)-Bourne(17%)-Faceville(16%)	11,150	3.7
10.	Marlboro(21%)-Coxville(19%)-Faceville(11%)	6,894	2.2
11.	Coxville(22%)-Duplin(21%)-Marlboro(16%)	10,958	3.6
12.	[Gravelly and Clayey Soils(28%)-Vaucluse(12%)-Kempsville(10%)	8,306	2.7
13.	Marlboro(24%)-Faceville(17%)-Bourne(14%)	24,702	8.2
14.	Faceville(28%)-Kempsville(12%)-Sassafras(11%)	9,007	3.0
15.	Sassafras(26%)-Faceville(20%)-Orangeburg(10%)	10,074	3.3
16.	Sassafras(28%)-Sassafras T.S.P.(15%)-Faceville(10%)	16,790	5.6
17.	Sassafras(23%)-Kempsville(22%)-Marlboro(10%)	14,490	4.8
18.	Craven(30%)-Marlboro(11%)-Caroline(10%)	6,010	2.0
19.	Augusta(21%)-Chewacla(20%)-Altavista(11%)	4,950	1.6
20.	Pamunkey(30%)-Altavista(12%)-Molena(10%)	19,970	6.6
21.	Roanoke(24%)-[Mixed Alluvial Soils](22%)-Altavista(10%)	6,362	2.1
22.	Chewacla(24%)-Wehadkee(19%)-[Fresh Water Swamp] (10%)	3,887	1.3
	Water	3,200	1.1

KEY TO SOIL ASSOCIATION MAP, HANOVER COUNTY, VIRGINIA

I. Soils of the Piedmont formed on residuum of granite, granite gneiss, and hornblende gneiss.

Soil Associations: 1, 2, 3, 4 and 5.

II. Soils of the Piedmont formed on residuum of metamorphosed and sedimentary rocks.

Soil Associations: 6, 7 and 8.

III. Soils formed on thin Coastal Plain sediments overlying Piedmont residuum.

Soil Associations: 9 and 10.

IV. Soils formed on the Coastal Plains with medium and light textured subsoils.

Soil Associations: 11, 12, 13, 14, 15, 16 and 17.

V. Soils found on the Coastal Plain with clayey and medium textured subsoils.

Soil Association: 18.

VI. Soils of the Piedmont river terraces and flood plains formed on recent alluvium; fresh water swamps also included.

Soil Associations: 19, 20, 21 and 22.

SOURCE: (SOILS OF HANOVER CO., VIRGINIA P. 349-351)

CHAPTER III

GEOLOGY

Regional Geologic Setting

The geological evolution of Hanover County has been characterized in the Piedmont section by eutectonic uplifting, intervals of granitic injection, and normal faulting; and in the Coastal Plain section by continual basement subsidence with subsequent marine and fluvial deposition of regressive and transgressive sediments.

The Fall Zone marks the border between the region of erosional processes to the west (Piedmont) and the region of terrigenous and marine depositional processes eastward (Coastal Plain) (Figure 3).

The Applachian Orogenic Revolution (Silurian to Permian Periods, 420 to 280 million years ago; Table 2) and associated eutectonic uplifting has enabled the igneous and metamorphic rocks of the Piedmont to act as an abundant sediment source for the depositional filling of the Coastal Plain from Cretaceous to Recent time. Continental tectonic movements in the Coastal Plain section have produced an eastward downsloping of the basement (Figures 5a and 5b) during Coastal Plain sediment deposition.

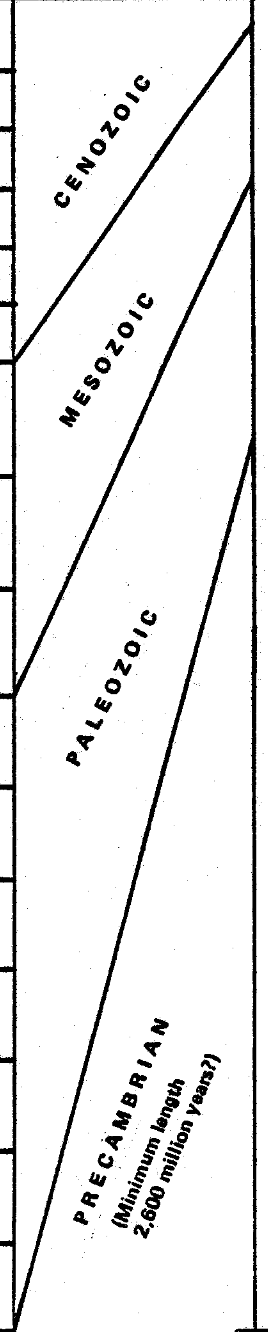
Granitic injection occurred in the easternmost Piedmont during Paleozoic time. During Triassic time, normal faults and their associated basins were formed following a release of east-west pressure between the European and American Continental Plates. The deposition of marine and fluvial, regressive and transgressive sediments has continued in the Coastal Plain from the Cretaceous Period to the Present with the existing north-south trending Fall Zone containing the westernmost remnants of Coastal Plain sedimentation.

In view of the many differences between the geologies of the Piedmont, Coastal Plain, and the Fall Zone and the direct effect these differences have on groundwater quality and production, each will be analysed separately in this report.

Table 2. Scale of Geologic Time

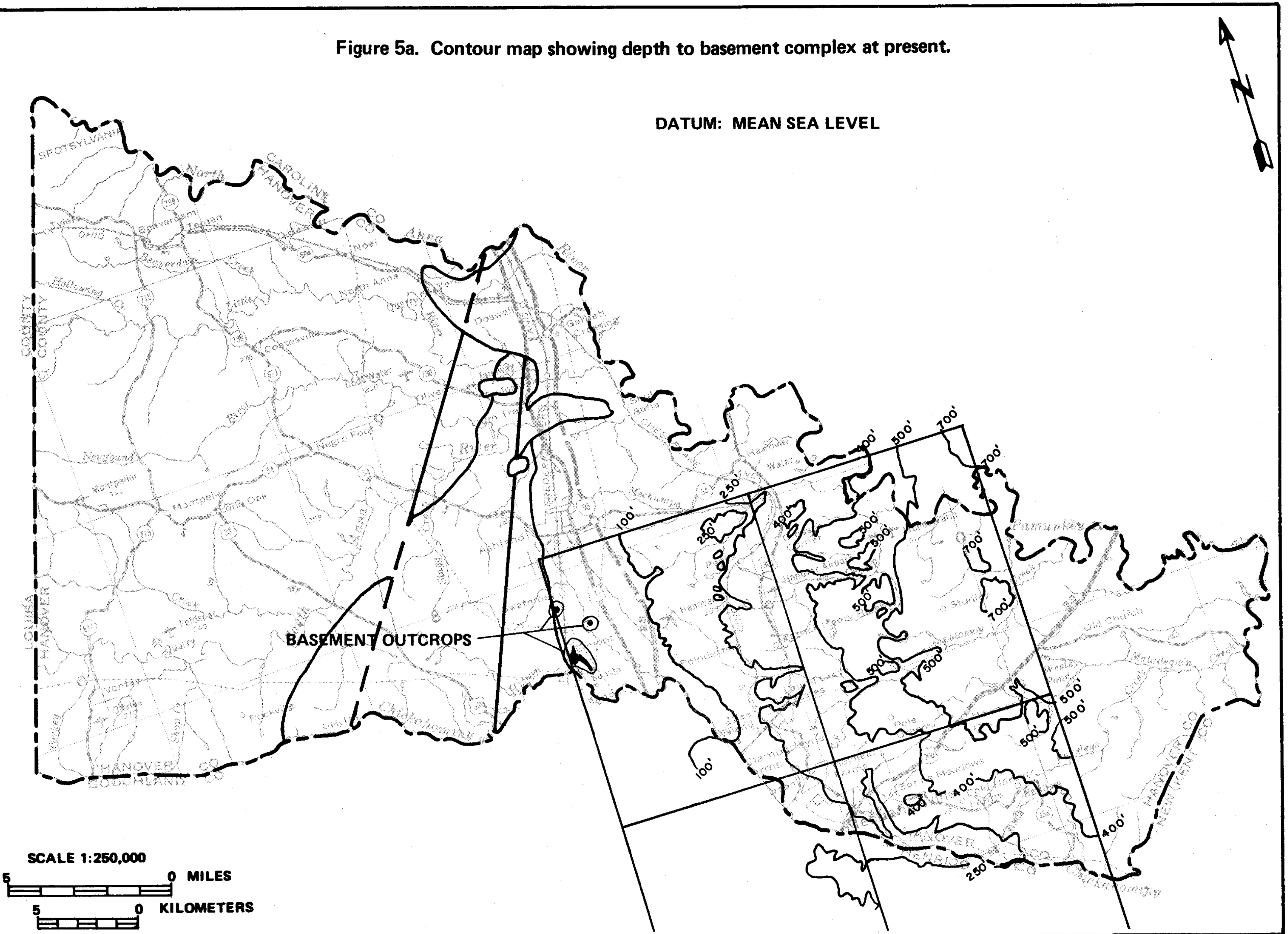
Subdivisions of Geologic Time				Apparent Ages (millions of years before the present)
Eras	Periods	Epochs	Ages	
CENOZOIC	Quaternary	(Recent) Pleistocene		
				2.5(?)
	Tertiary	Pliocene		
				13
		Miocene		
				25
		Oligocene		
				36
		Eocene		
				58
		Paleocene		
				63
MESOZOIC	Cretaceous			
				135
	Jurassic			
				180
	Triassic			
				230
PALEOZOIC	Permian			
				280
	Pennsylvanian			
				310
	Mississippian			
				340
	Devonian			
				400
	Silurian			
				430
	Ordovician			
				500
	Cambrian			
				600
PRECAMBRIAN (No worldwide subdivisions)				

Relative Lengths of Major Time Divisions, to True Scale



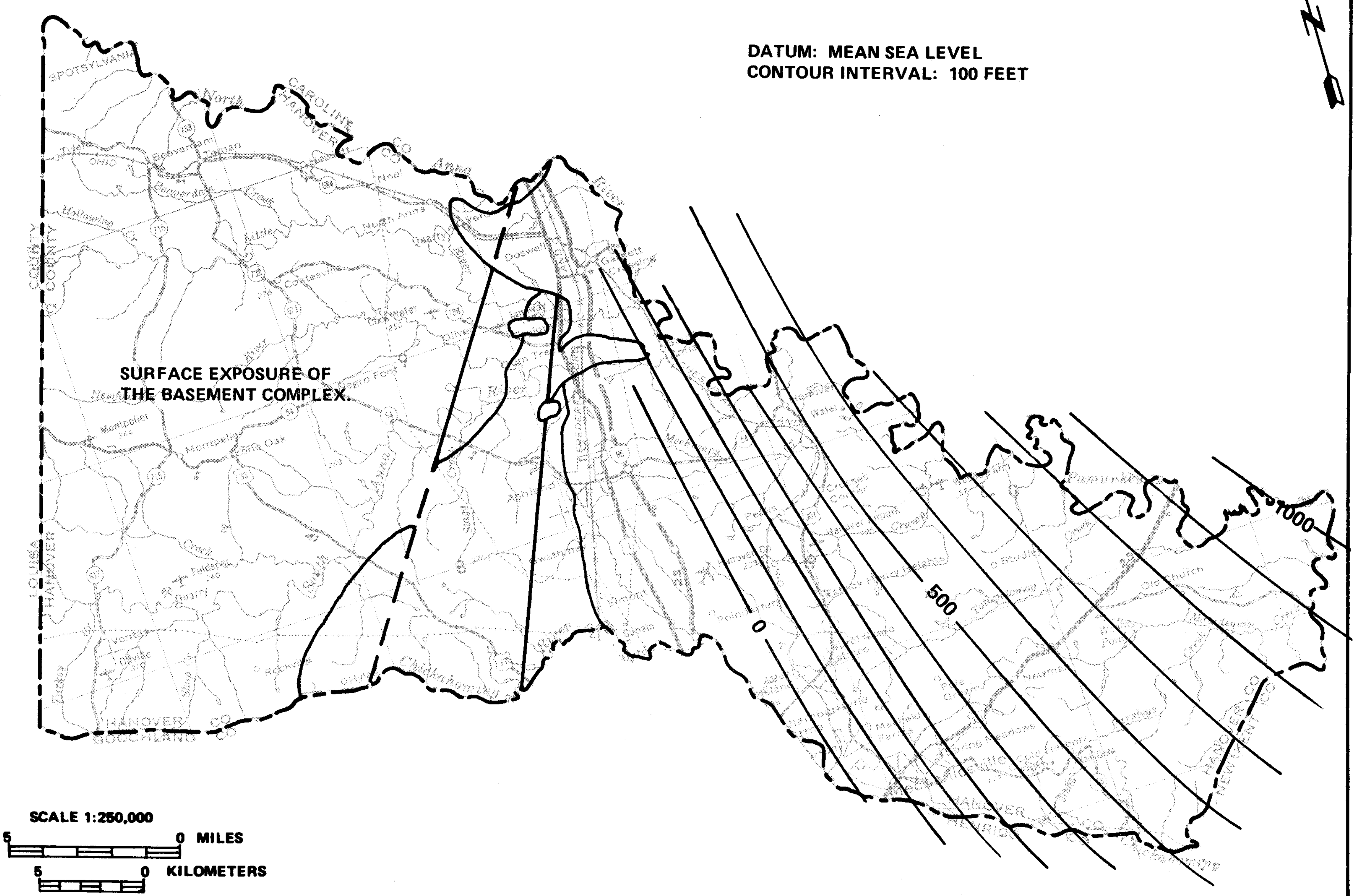
SOURCE: LONGWELL, FLINT, SANDERS (1969), P. 132

Figure 5a. Contour map showing depth to basement complex at present.



SOURCE: DANIELS & ONUSCHAK, (1974) PLATE NO. 6.

Figure 5b. Contour map on top of basement complex.



SOURCE: TIEFKE (1973).

Piedmont Geology

The Piedmont section of Hanover County is made up of different rock units ranging in age from Precambrian to Triassic (Figure 6). The predominant rock types in this section include the crystalline igneous and metamorphic rocks, with minor exposures of consolidated sedimentary rocks. The consolidated sedimentary rocks are Triassic in age. They are included in the Piedmont because of their age, location, and well-consolidated nature.

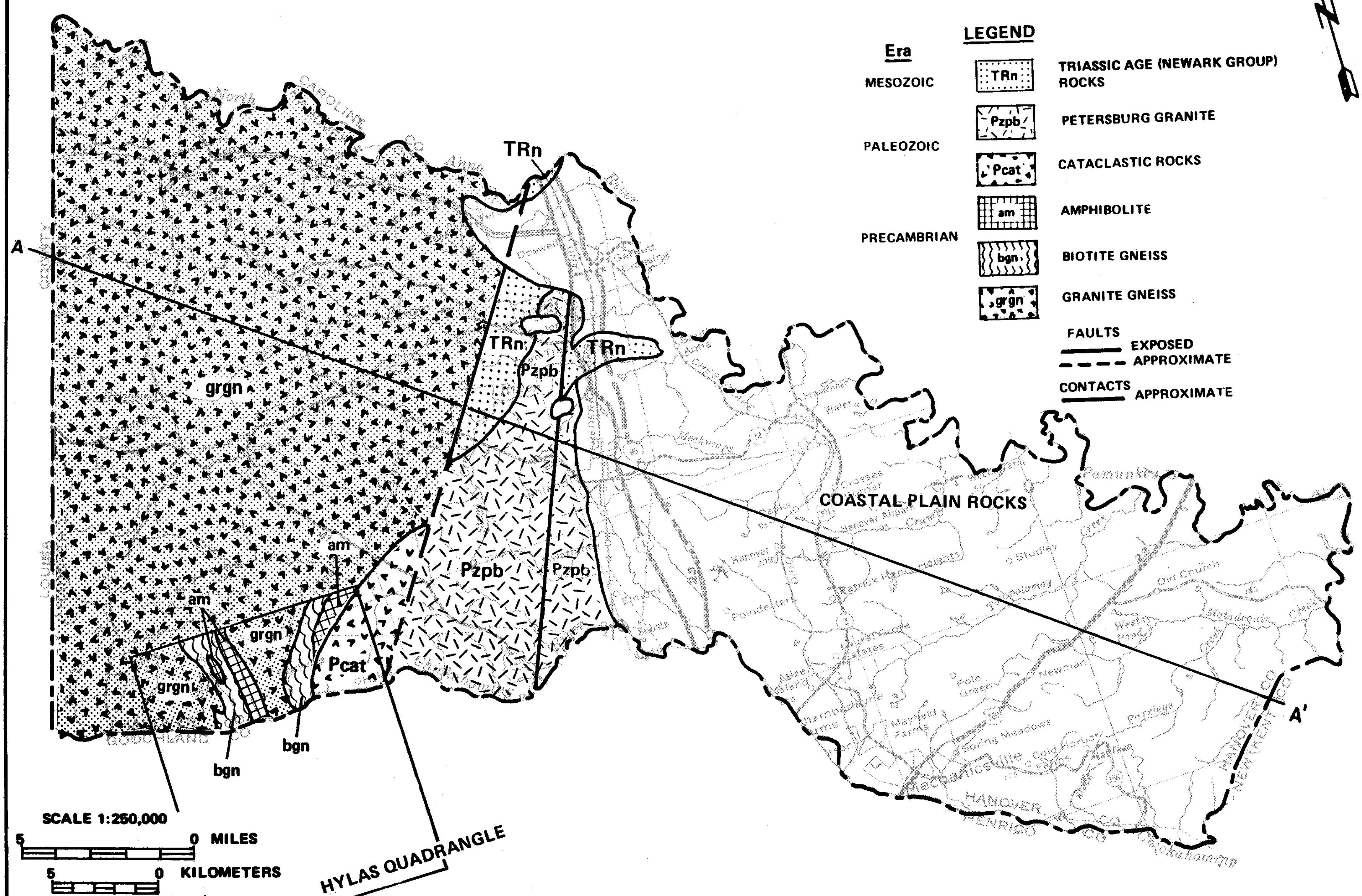
Both crystalline and well-consolidated rock types are resistant to weathering. Differential weathering of these rocks has caused the characteristic hilly Piedmont terrain. Eastward, the Piedmont rocks are covered in the Fall Zone by unconsolidated sediments of Cretaceous age and younger. Drill cuttings obtained from wells drilled in the Coastal Plain show that crystalline and well-consolidated Piedmont rocks exist at ever increasing depths eastward (Figures 5a and 5b). These rock units are collectively referred to as the "basement complex."

Through time, weathering processes have disintegrated, eroded, and transported vast amounts of Piedmont rock debris. The in-place, disintegrated, crystalline and consolidated rocks are referred to as saprolite. Saprolite varies in thickness from zero to several hundred feet, with zero indicating a hardrock outcrop. It is important to note that, throughout the Piedmont of Hanover County, the depth and composition of the saprolite has a direct effect on the quality and quantity of shallow sources of groundwater. This is due to the fact that the shallow groundwater potential in any area is directly related to the depth and extent of the saprolite. Groundwater quality increases with greater thicknesses of saprolite. The eroded and transported Piedmont material (saprolite) is believed to have been the major source of what is now called Coastal Plain deposits.

Coastal Plain Geology

General Stratigraphy. The Coastal Plain is composed predominantly of unconsolidated marine and non-marine clays, silts, sands, and gravels that were deposited during episodes of marine transgression and regression

Figure 6. Geologic map of the Piedmont in Hanover County.



SOURCE: GEOLOGIC MAP OF VA. (1963); B. K. GOODWIN (1970), HYLAS QUADRANGLE.

Figure 7a. Geologic Map of the Coastal Plain in Hanover County.

Legend for the Coastal Plain outside of the four quadrangle area (Based on Geologic Map of Virginia, 1963)

GEOLOGIC TIME	Symbol	Formation
MIOCENE	Ty	Yorktown Formation
	Ts	St.Mary's Formation
	Tc	Calvert Formation
EOCENE	Tn	Nanjemoy Formation
	Ta	Aquia Formation
CRETACEOUS	Kptx	Patuxent Formation

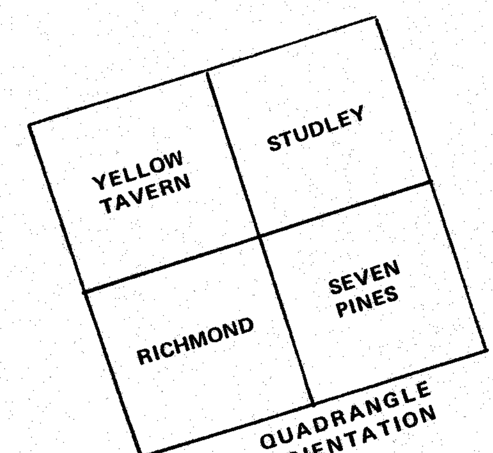
Legend for Studley, Yellow Tavern, Seven Pines, and Richmond quadrangles

GEOLOGIC TIME	Symbol	Unit	
CENOZOIC	al	Alluvium	QUATERNARY
	sg	Regressive Sand and Gravels	TERTIARY
	cs	Transgressive Clayey-silt	TERTIARY
	TK	Tertiary and Cretaceous Sediments	TERTIARY
MESOZOIC	Kptx	Patuxent Formation	CRETACEOUS
PALEOZOIC	Pzpb	Petersburg Granite	

FAULTS

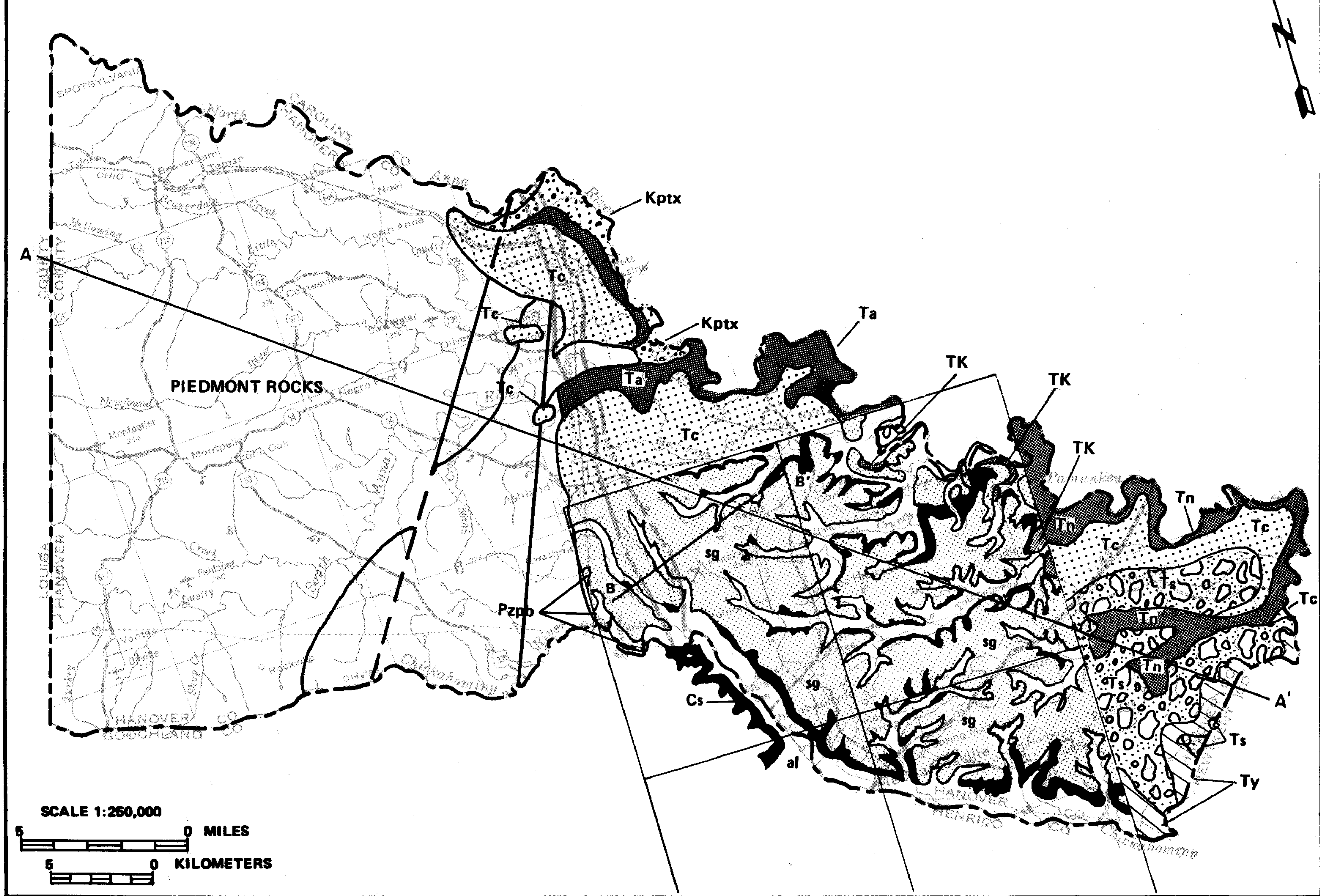
— — — APPROXIMATE

CONTACTS APPROXIMATE



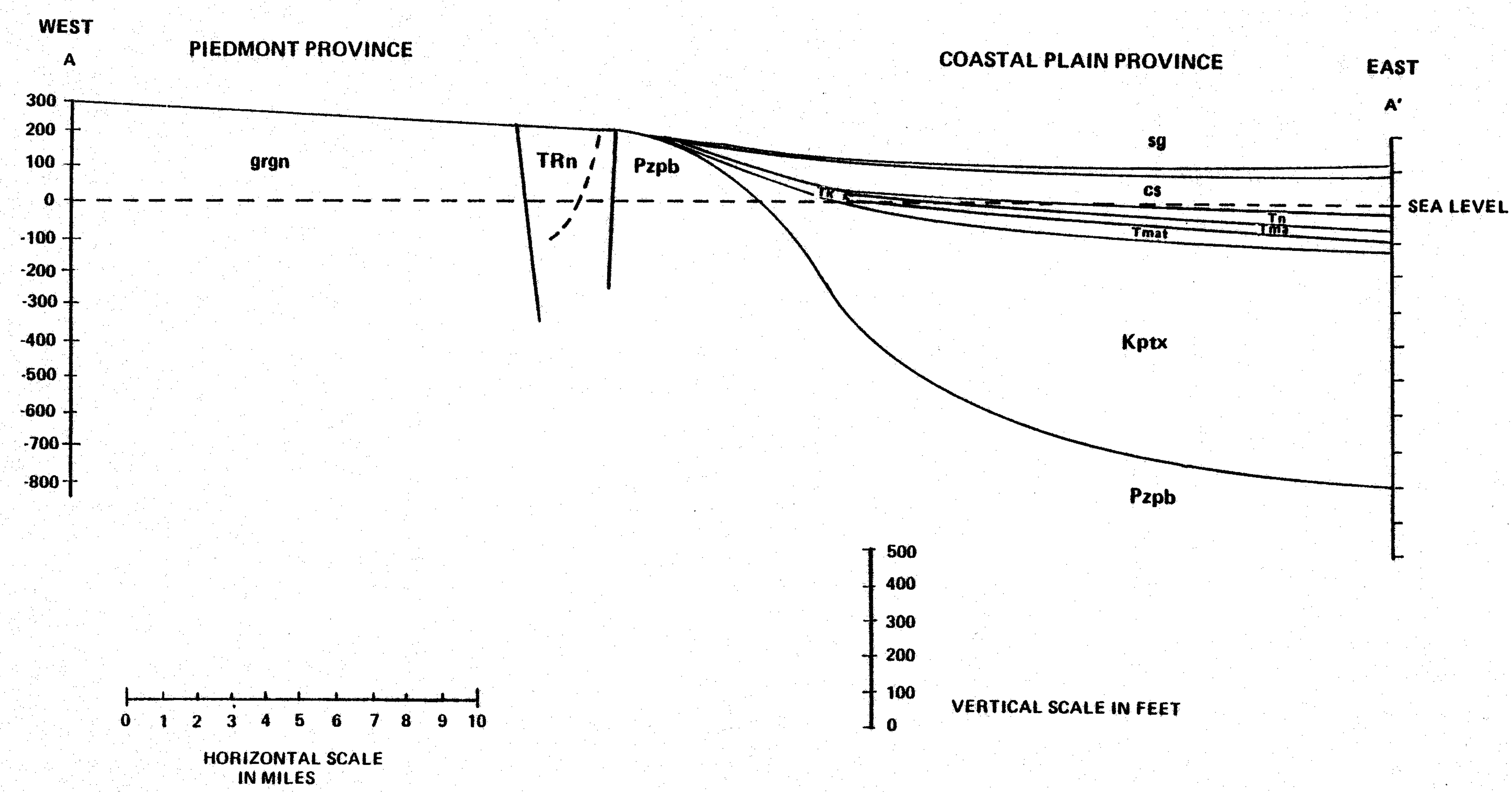
QUADRANGLE ORIENTATION

Figure 7a. (Continued) Geologic Map of the Coastal Plain in Hanover County.



SOURCE: GEOLOGIC MAP OF (1963) ; VDMR-R.I. 38

Figure 7b. Interpretive section through the Piedmont and Coastal Plain from A to A′. (See Figures 6 and 7a for cross-section location).



SOURCE: STATE WATER CONTROL BOARD – PRO

from the Cretaceous to the Present. Table 3 gives the ages, names, and descriptions of the Coastal Plain formations. The unconsolidated sediments outcrop at the Fall Zone, where the westernmost occurrence of the Cretaceous and younger age deposits (Figure 7a) exists, and extend eastward to the Chesapeake Bay in an increasingly-thick sediment wedge. Thicknesses of 800 to 900 feet (244 to 274 meters) are noted at the eastern border of Hanover County. Piedmont "basement complex" rocks underlie this vast wedge of sediment (Figure 7b).

In the broad west-east cross-section (Figure 7c), sediments are represented as having evolved from fluvial processes, marine transgression and regression, and deep-marine deposition. Many minor fluctuations have occurred during the marine transgressions and regressions, thus making the localized geologic structure more complex than that represented in this cross-section.

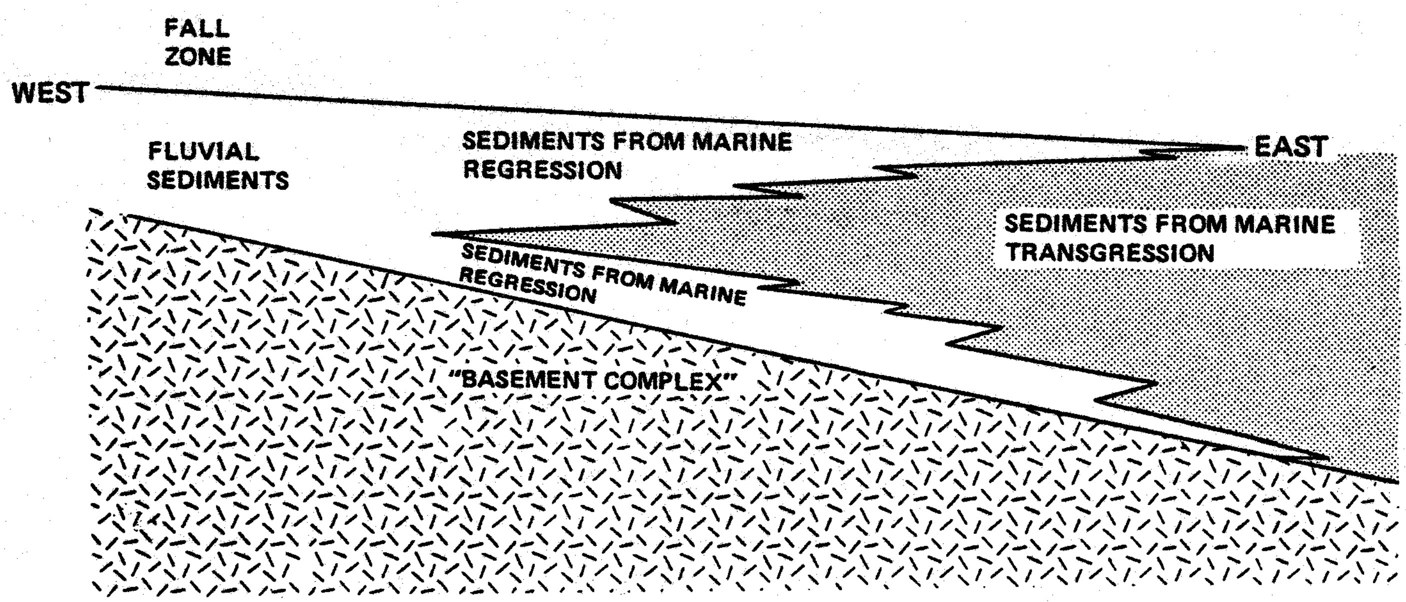


FIGURE 7c. WEST-EAST, GENERALIZED, CROSS-SECTION, DEPICTING MARINE REGRESSIVE AND TRANSGRESSIVE DEPOSITION IN THE COASTAL PLAIN PORTION OF HANOVER COUNTY

During early Cretaceous time, the depositional environment was predominantly fluvial, with clastic sands and gravels of the Patuxent

Table 3. Coastal Plain geologic units and their waterbearing characteristics

System	Series	Formation	Aquifer Designation in this Report	Approximate Thickness (Feet)	Lithologic Character and Origin	Hydrologic Comments
Quaternary		Alluvium	Water Table System	0-20	Unconsolidated sand, clay, and gravel of fluvial and marine deposition. Surficial terraces and dunes.	Supplies groundwater to low yield water table wells throughout the area.
		sand and gravel (regressive sediments)		0-70		
Tertiary	Miocene	Yorktown Formation (absent)	confining units	0-100	Clays and silty clays, plant and shell material locally abundant. Coarse basal sand. Marine deposition.	Acts as a confining unit for the upper artesian system. The basal sand is part of the upper artesian aquifer system
		Clayey silts (transgressive sediments)				
	Eocene	Nanejemoy Formation	upper artesian system	0-80	Quartz-glauconite sands. Shell beds common. Marine desposition.	Yield sufficient water for domestic, subdivision, and light industrial purposes.
	Paleocene	Mattaponi Formation	confining units	0-200	Highly glauconitic sands, silts, and clays. Often referred to as "greensand" or "blacksand" marine origin.	Generally an aquitard confining layer for principal aquifer system
Cretaceous	Upper					
	Lower	Patuxent Formation	Principal artesian system	0-550	Interbedded gravels, sands, silts, and clays of fluvial and deltaic origin. Some thin marginal marine beds.	Capable of high yield with proper development
Triassic and Paleozoic		"basement"			Igneous and metamorphic and partly consolidated shales and sandstones.	Supplies moderate quantities of groundwater to wells near Fall Zone

(Source: Tiefke, 1973; SWCB-BWCM)

Formation (Kptx) being laid down upon the "basement complex" in prograding deltas where ancient drainages emptied into shallow-water bodies to the east (Daniels and Onuschak, 1974, p. 7). These sediments were reworked as the eastward-prograding deltas were affected by frequent marine encroachments. These Lower Cretaceous (Patuxent Formation) clastic sediments increase in thickness from tens of feet at the Fall Zone to hundreds of feet at the eastern border of Hanover County.

Transgressive and estuarine sediments were deposited on top of the Patuxent sands and gravels as the sea advanced and receded. These sediments were deposited during the Late Cretaceous and Early-to Middle-Tertiary Period, and are generally of drab, grayish colors, laterally and vertically homogeneous and with a well-sorted texture (Daniels and Onuschak, 1974, p. 7). The deposits are referred to as the Mattaponi Formation (Paleocene and Eocene Epochs) with an erosional unconformity characterizing its surface. Next, in Middle-to Late-Eocene, the Nanjemoy Formation was deposited by near-shore marine processes. It is referred to as a "greensand" (abundant in clay and glauconite). It, too, is characterized by a surface, erosional unconformity.

The last major episode of marine transgression occurred in Middle-Miocene time with the deposition of the "clayey silt". This unit is fossiliferous and consists of drab, greenish-brown clays and silty clays. These deposits include the "Miocene Marl", Calvert Formation (Darton, 1911), and St. Mary's Formation. The absence of an upper-surface, erosional unconformity, and a lack of glauconite differentiate these transgressive deposits from the older underlying Mattaponi and Nanjemoy Formations (Daniels and Onuschak, 1974, p. 8).

Later, in the late Tertiary and Quarternary, the sea receded and fluvial (regressive) processes predominated again. These deposits, referred to by other authors as the Columbia Group, Brandywine Formation, and Lafayette Formation, are mostly land-derived clastic materials. The regression of the sea continues to the present time. Much of the recently-deposited alluvium is derived from erosion of Tertiary regressive sediments.

CHAPTER IV

GEOHYDROLOGY

General

Geohydrology is defined as the study of groundwater and its subsurface relationships with the surrounding geology. Groundwater represents only one stage in the movement of water through the hydrologic cycle (Figure 8). The groundwater portion of this cycle is dependent upon the amount and frequency of precipitation received in a given area and, perhaps more specifically, the portion of the precipitation which has been allowed to infiltrate into the subsurface. It is this portion of the hydrologic cycle, precipitation and infiltration, which is responsible for eventually recharging all groundwater resources. Infiltration is the key to the quantity of groundwater available as a resource.

Precipitation which infiltrates into the subsurface must pass through pores and openings in the earth's outer crust (soil cover and surface rock) as well as through rocks in the subsurface. Groundwater, therefore, passes through a zone of aeration, which includes a soil-water belt, an intermediate belt, and a capillary fringe. Finally it percolates down into a zone of saturation which is the groundwater reservoir. Soil conditions, vegetation, soil chemistry, topography, rock types, and geologic structure all influence the quantity and quality of groundwater. Of these influencing factors, topography, rock type, and geologic structure are the major factors controlling the recharge, storage, quality, and yield of a groundwater resource. These factors will be discussed below. It should be stressed that many parameters which affect groundwater are all interrelated and, therefore, have a complex impact on the quantity, quality, and retrievability of this valuable resource.

Topography. The topography in the Hanover County area is dependent primarily upon the existing rocks' resistance to weathering. Topographically high areas are generally characterized by well-consolidated, unfractured bedrock or areas of impermeable clays. These high areas can be contrasted to areas dominated by fractured, jointed, or unconsolidated rocks and sediments which became the topographic lows by faster, downward erosion. Many of the naturally-flowing streams and springs that subsequently occupy these topographically low areas are also the surface expression of the groundwater table.

Infiltration is greatly dependent upon slope and rock structure. Steeply-sloping land areas cause rapid rain runoff, allowing very little time for infiltration to occur. Conversely, gently-sloping to flat areas allow longer retention times for the infiltration of precipitation. The geologic structure has a similar impact on runoff and infiltration.

Water that infiltrates into the subsurface eventually recharges the groundwater reservoir. The surface of this reservoir, or zone of saturation, usually parallels the surface topography. The groundwater migrates downslope, i.e. from topographic highs to topographic lows (Figure 9). Thus, most low-lying areas have a greater potential as a groundwater source than the high areas. Consequently, these low-lying areas are affected to a lesser degree by drought conditions.

Rock. As used in this report, the terms "rock" and "rock unit" will mean both consolidated and unconsolidated materials. Each rock or rock unit is differentiated by its specific external and internal physical and chemical characteristics. These characteristics greatly affect groundwater quality and quantity.

The most important physical characteristics of a rock or rock unit which affect its water bearing capabilities are its porosity and permeability. Porosity is defined as the volume of a rock unit which is not occupied by solid material. It directly relates to the groundwater storage capacity of the unit. Permeability is defined as the capacity of the rock unit to allow groundwater transmission. It is a measure of the rock's ability to transmit its stored groundwater. Both the porosity and permeability of any rock unit are dependent upon the size and orientation of its mineral grains (Figure 10). For example, a highly permeable and porous rock is ideal for groundwater infiltration, storage, and production (i.e.: sand). In contrast, a rock unit such as clay can possess a high degree of porosity, but have low permeability and, therefore, be a very poor groundwater producer.

The chemical composition of the rock unit affect or determines the water quality. Therefore, various minerals composing the rock unit

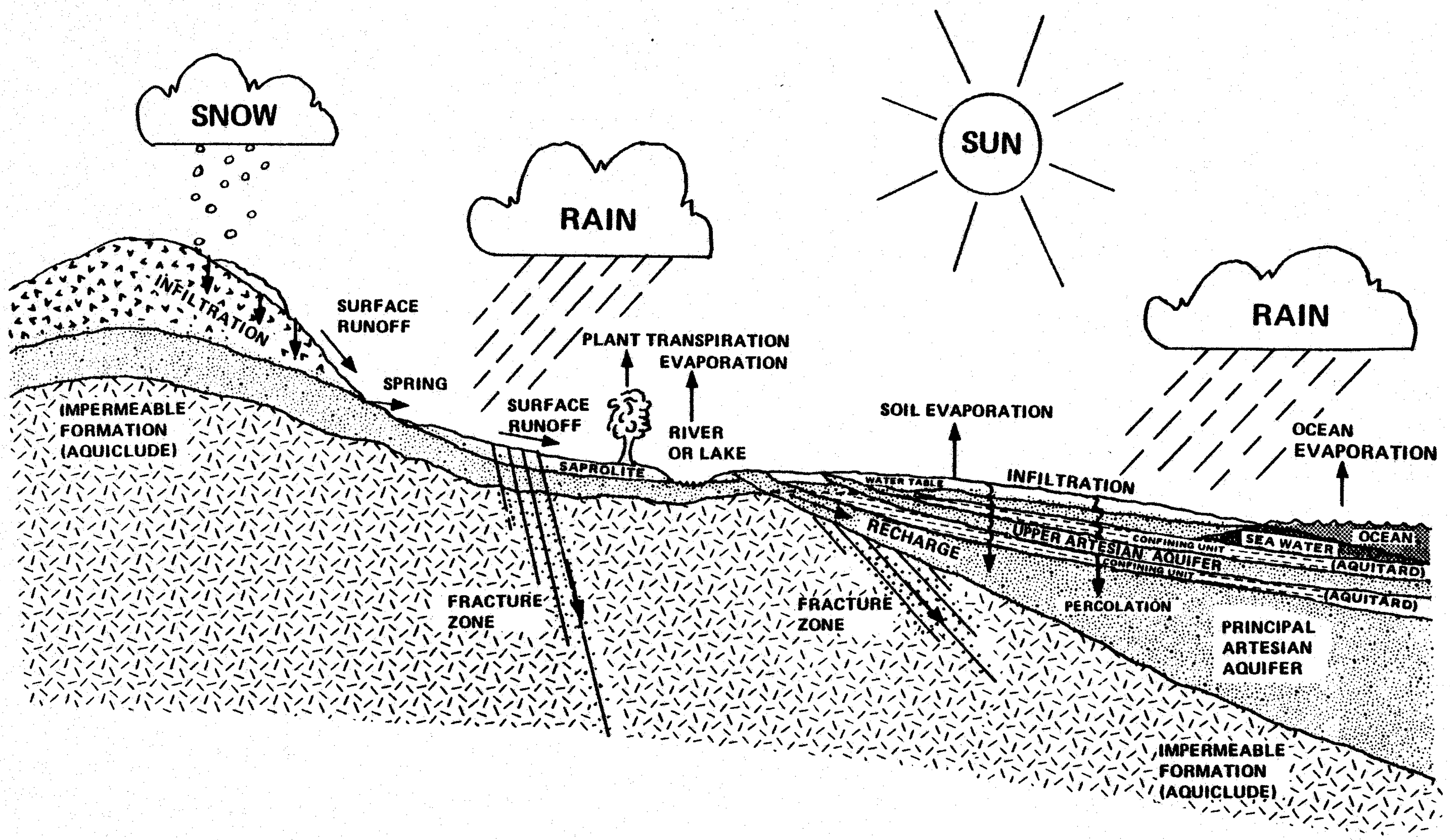
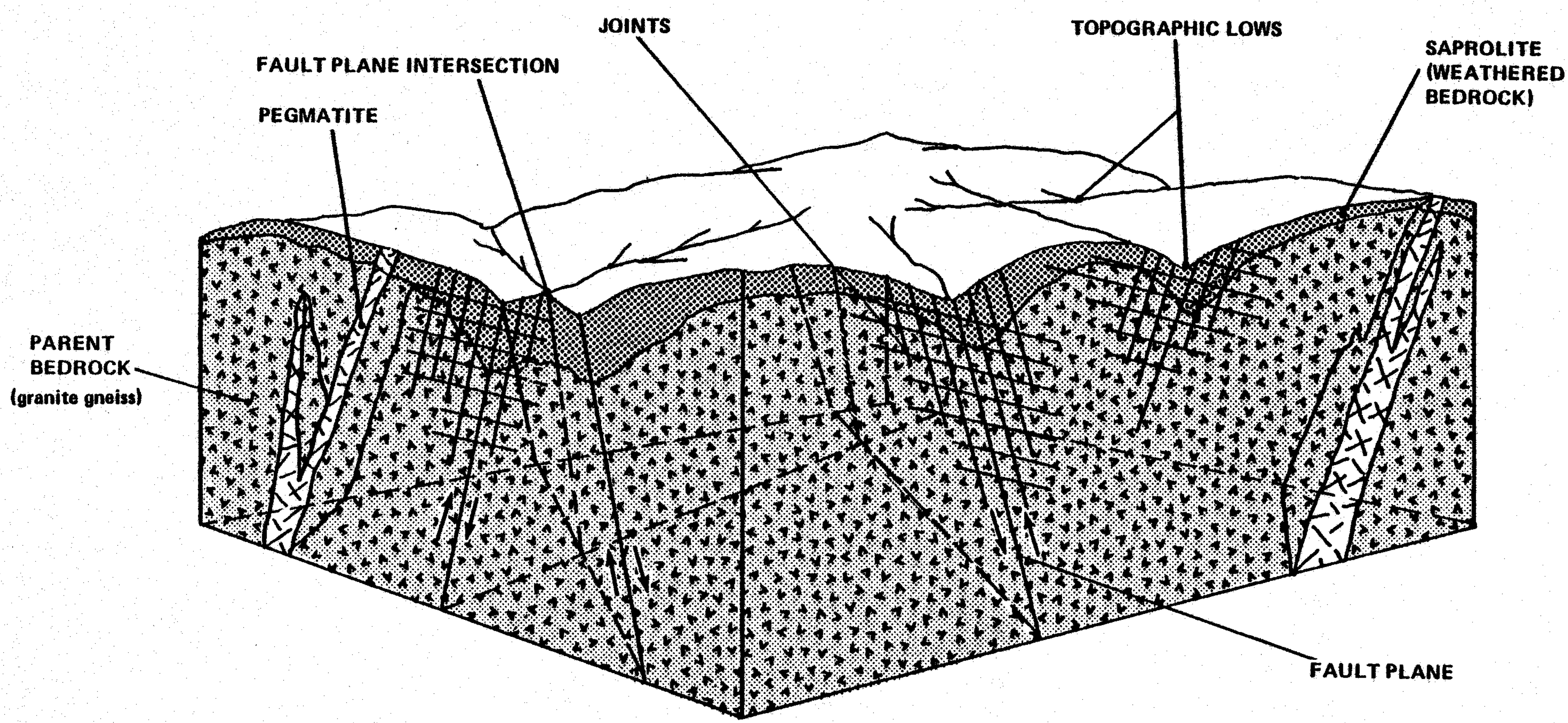


Figure 8. Hydrologic Cycle

SOURCE: STATE WATER CONTROL BOARD – PRO

Figure 9. A schematic diagram showing the subsurface cross section of typical fractured and jointed Piedmont rocks.

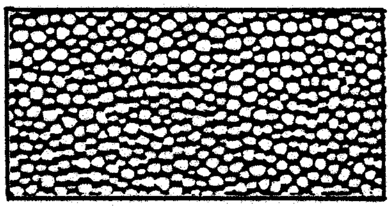


SOURCE: STATE WATER CONTROL BOARD -- PRO

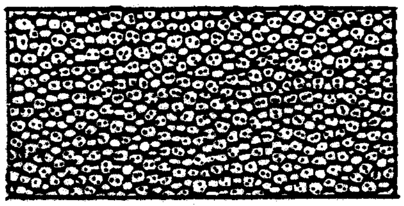
Figure 10. Diagramatic representations showing examples of porosity and permeability.

EXAMPLES OF POROSITY –

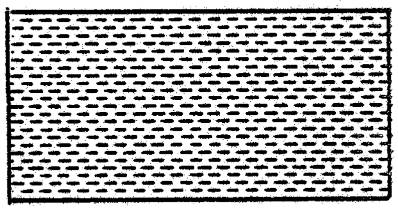
– Porosity is the amount of pore space, or volume of a formation which is not occupied by solid material.



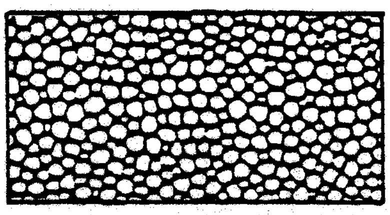
– Well-Sorted, Medium Size Sediment (High Porosity)



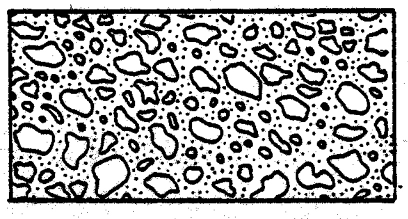
– Well-Sorted Medium Size Sediment with Porous Grains (Very High Porosity)



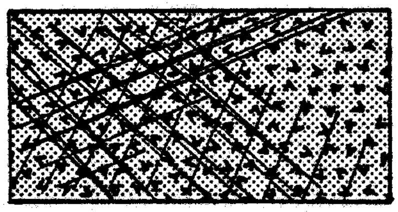
– Clay (High Porosity)



– Well-Sorted Gravel - (Very High Porosity)



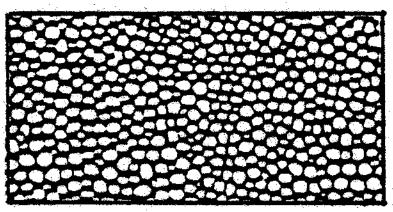
– Poorly Sorted Sediment (Low Porosity)
– If Intergranular Space is Cemented - (Very Low Porosity)



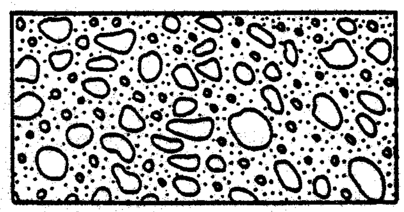
<u>Piedmont Type Bedrock</u>
– Cavities Developed Along Fractures and Joints (Very High Porosity)
– Interconnected Fractures (High Permeability)

EXAMPLES OF PERMEABILITY

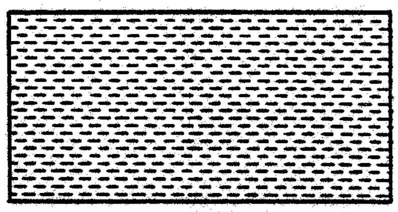
– Permeability is the capacity of a porous medium to transmit water.



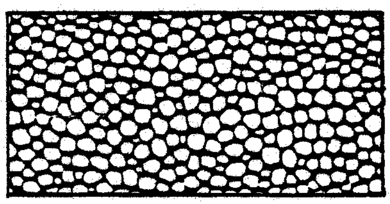
– Well-Sorted, Medium Size Sediment (High Permeability)



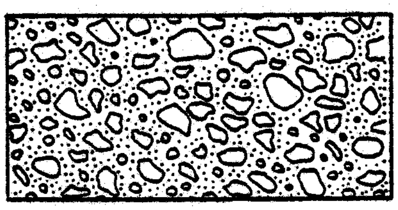
– Poorly Sorted Sediment (High Permeability – Lower than Well Sorted, Coarse Sediment)



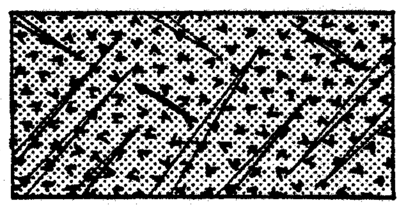
– Clay (Very Low Permeability)



– Well-Sorted, Gravel (Highest Permeability)



– Poorly-Sorted Sediment, Cemented Inter-Granular Spaces (Very Low Permeability)



<u>Piedmont Type Bedrock</u>
– Non-Connecting Fractures and Joints (Very Low Permeability)

SOURCE: STATE WATER CONTROL BOARD – PRO

supply the chemical concentration as the groundwater percolates through it. Percolation rates (permeability) and the amount of time the water remains in intimate association with the rock are important factors in determining groundwater quality.

The terms aquifer, aquitard, and aquiclude describe the overall groundwater transmission characteristics (permeability) of a geologic formation and are tied directly to the rock type. An aquifer is described as a rock unit which allows the transmission and rapid well-recovery of groundwater. An aquitard is a rock unit which hinders groundwater movement but does allow some vertical and lateral movement without rapid well-recovery of its water. An aquiclude prohibits transmission of groundwater and contains no water.

Geological Structure. The geologic structure of an area refers to the attitude of the rock unit or formation. More specifically, this term refers to the regional disposition of the unit and includes its extent, thickness, strike, dip, joints, and faults. These structure characteristics can hinder or hasten groundwater recharge, movement, and storage. Vast extent of a water-bearing unit increases its groundwater storage capacity. Faults, joints, and vertical dip can increase the infiltration rate (recharge).

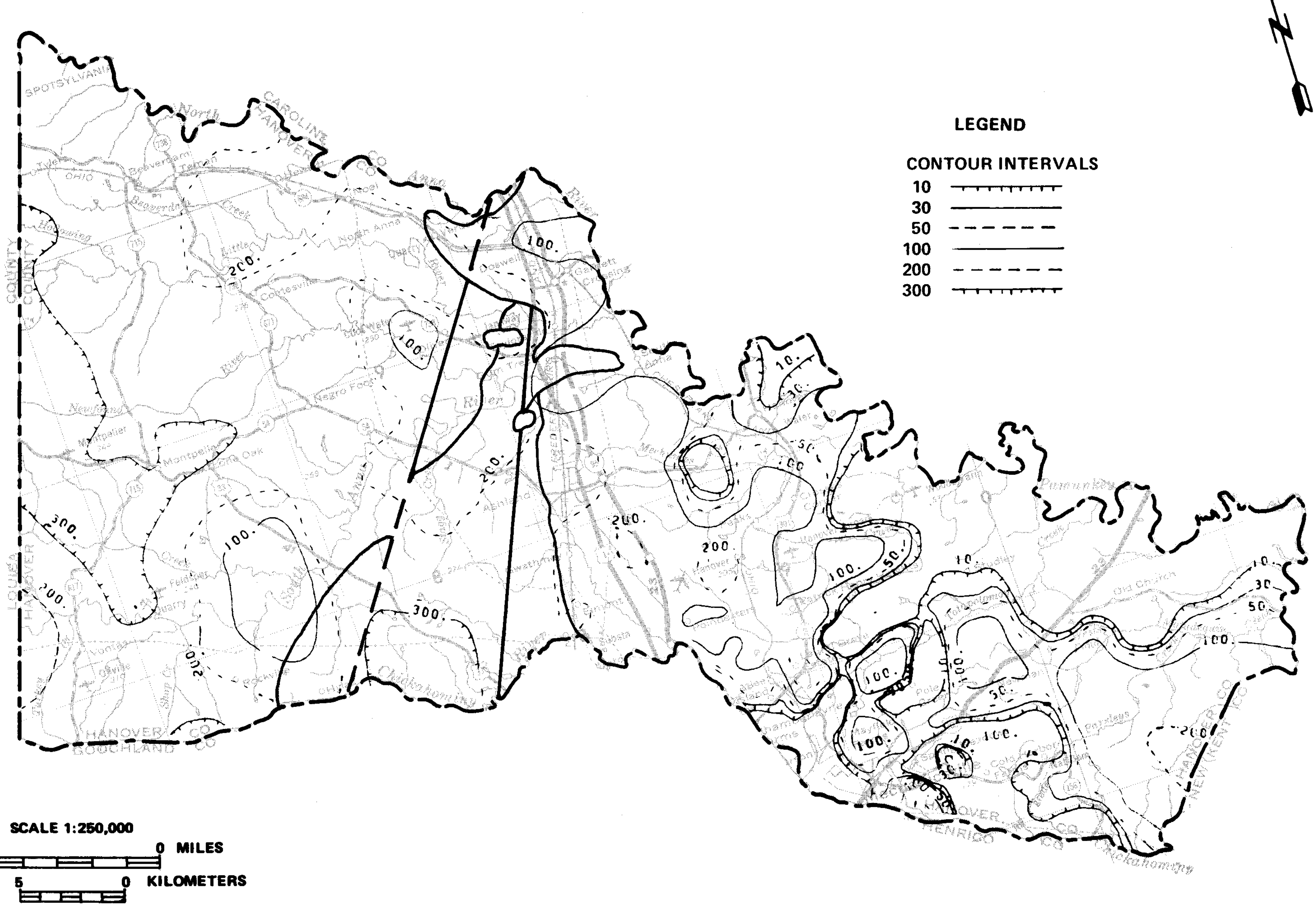
These major aspects of geohydrology can be used to develop a detailed analysis of the groundwater resources of Hanover County. The following sections will analyse the geohydrology of Hanover County.

General Geohydrology of Hanover County

Due to the diversity of the geology and related groundwater aquifers in Hanover County, the geohydrology of the Riedmont and Coastal Plain sections are discussed separately. The Fall Zone needs special attention because of its geologic complexity as the interface area between the Piedmont and Coastal Plain.

Some general aspects of the County's geohydrology can be determined from the State Water Control Board's water well data. A county-wide display of static water levels is shown in Figure 11. The depth from the land surface to the well water surface is defined as the static water

Figure 11. Countywide computer contour of static water levels.



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

level. This plot shows a general view of the existing static water levels in Hanover County and can indicate generally the depth at which groundwater is available. The static water levels in wells that tap artesian aquifers (Coastal Plain) reflect a distinctive hydrostatic head pressure and generally are much higher than the top of the water bearing formation.

Groundwater yields for the entire County have been contoured by computer with no regard for the aquifer, well size, pumping rate, etc. and are shown in Figure 12a. Figures 12b and 12c show an enlarged map of groundwater yields for the Piedmont and Coastal Plain sections, respectively. In general, it is shown that the potential groundwater yield is greater in the Coastal Plain than in the Piedmont section. In no way should this yield information be construed to represent maximum yields for any specific location. It only provides an overall view by county and physiographic province of what existing wells yield.

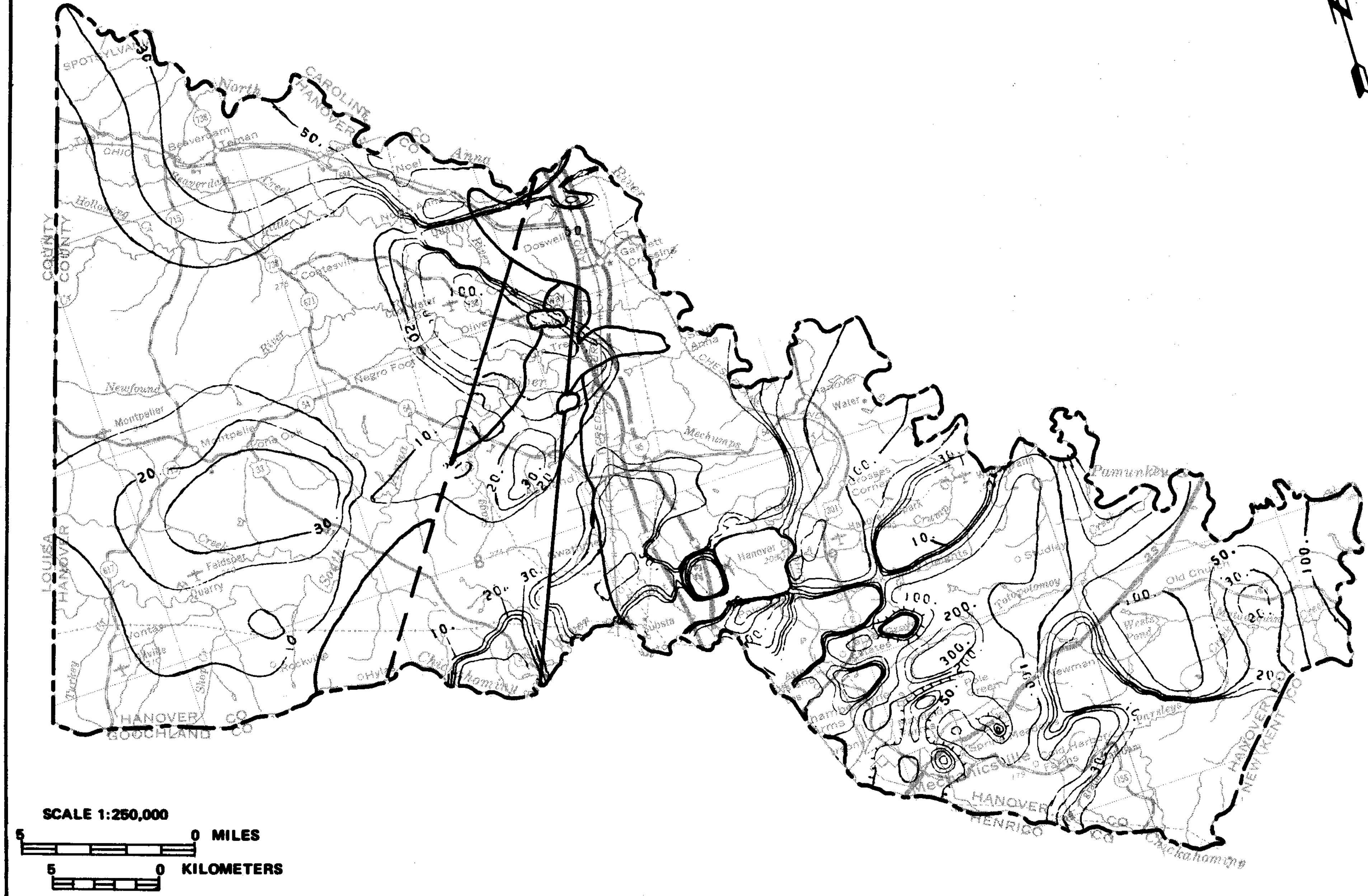
Piedmont Geohydrology

The Piedmont section of Hanover County contains Precambrian, Paleozoic, and Triassic age rocks. The geohydrology of these rocks is related intimately with the characteristics of the existing consolidated bedrock, the derived saprolite, associated faulting and jointing, and recent alluvial deposits. Their relationships are depicted in Figure 13. A discussion of Piedmont geohydrology will include Precambrian, Paleozoic, and Triassic age rock units.

Precambrian Rocks (600 million years old and older). The Precambrian-aged rocks extend from the western border of the County eastward to a northeast-southwest trending contact located near Verdon in the north, to a fault zone near Hanover Academy and east of Gilman in the central section, and then to a contact one mile east of Rockville in the south (Figure 6). The areal extent of these rocks is approximately 192.7 square miles (Figure 14).

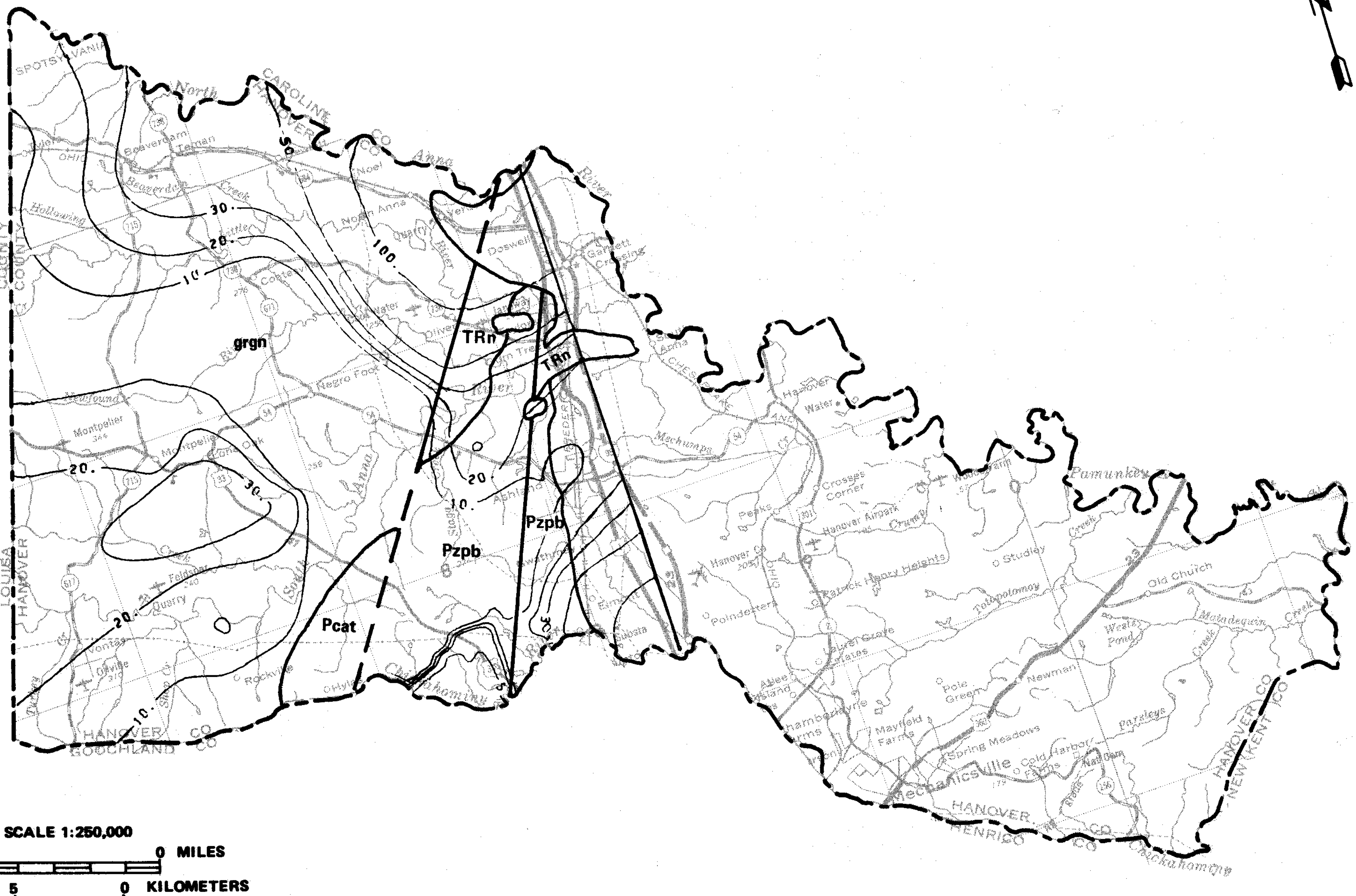
The most common Precambrian rock types encountered are granite gneiss (grgn), biotite gneiss (bgn), hornblende gneiss (hgn), and

Figure 12a. Countywide computer contour of groundwater yields.
Contour intervals: 0-10-20-30-50-100-200-300 (GPM).



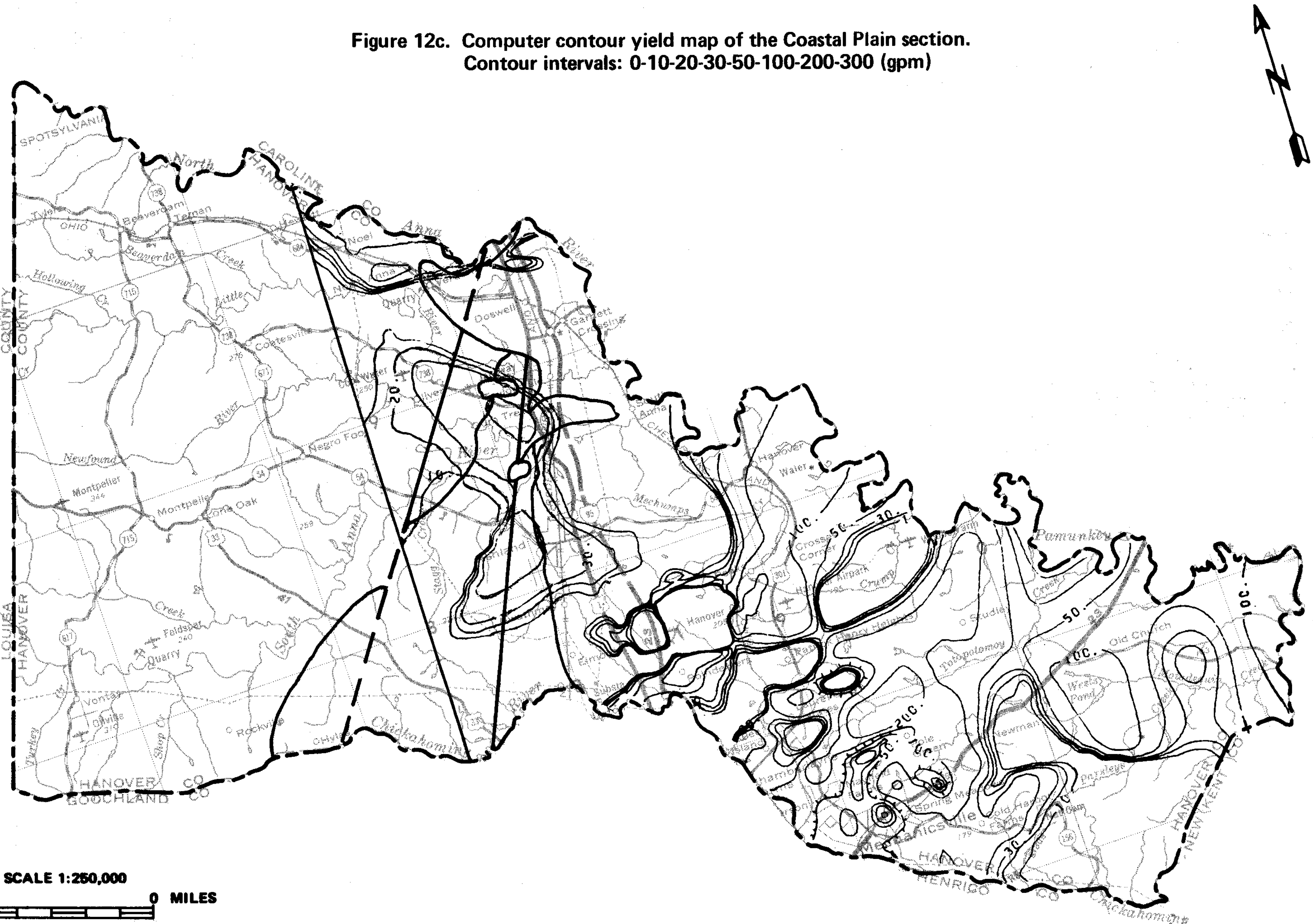
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 12b. Computer contour yield map of the Piedmont section.
Contour Intervals: 0-10-20-30-50-100-200-300 (gpm).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 12c. Computer contour yield map of the Coastal Plain section.
Contour intervals: 0-10-20-30-50-100-200-300 (gpm)



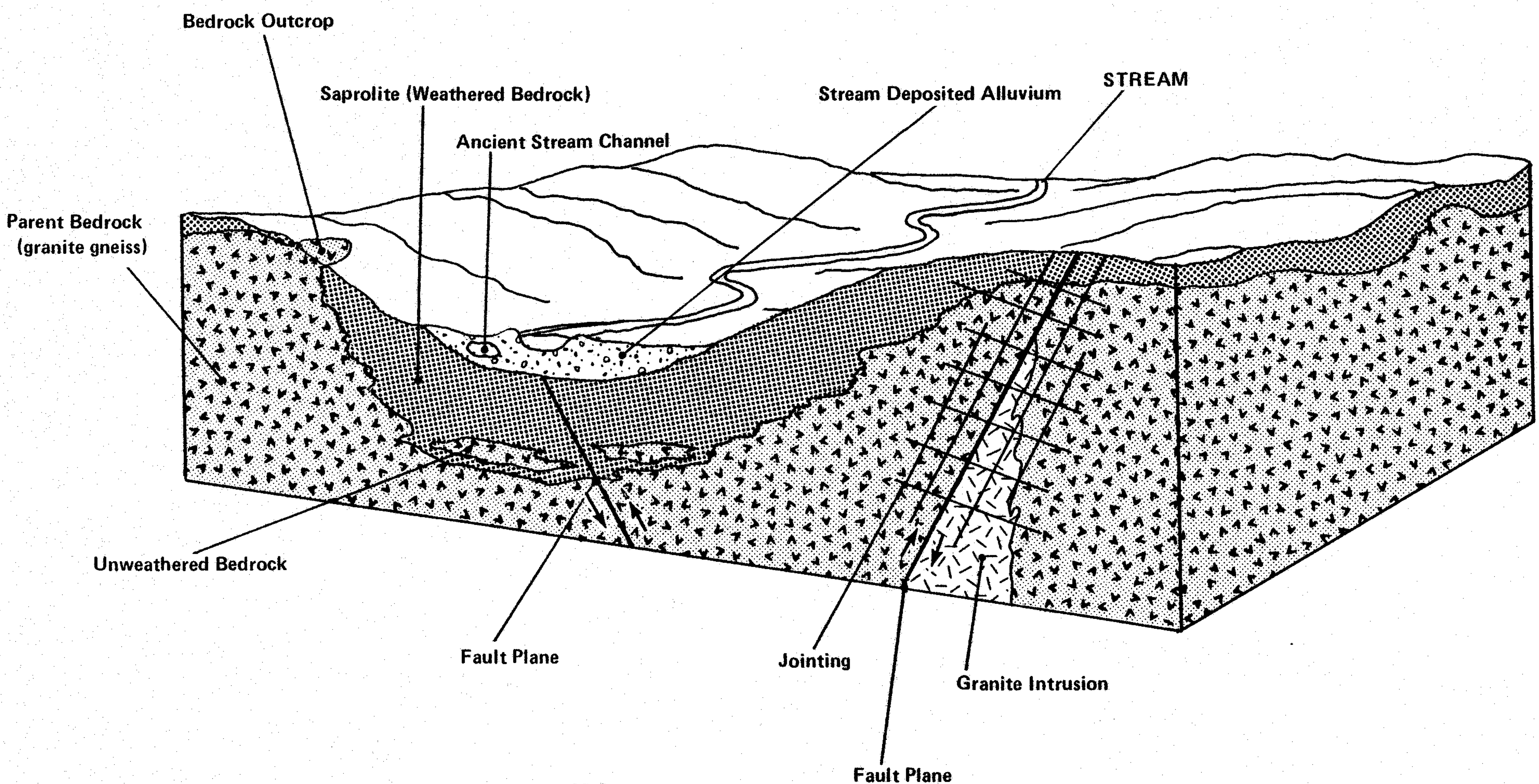
SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

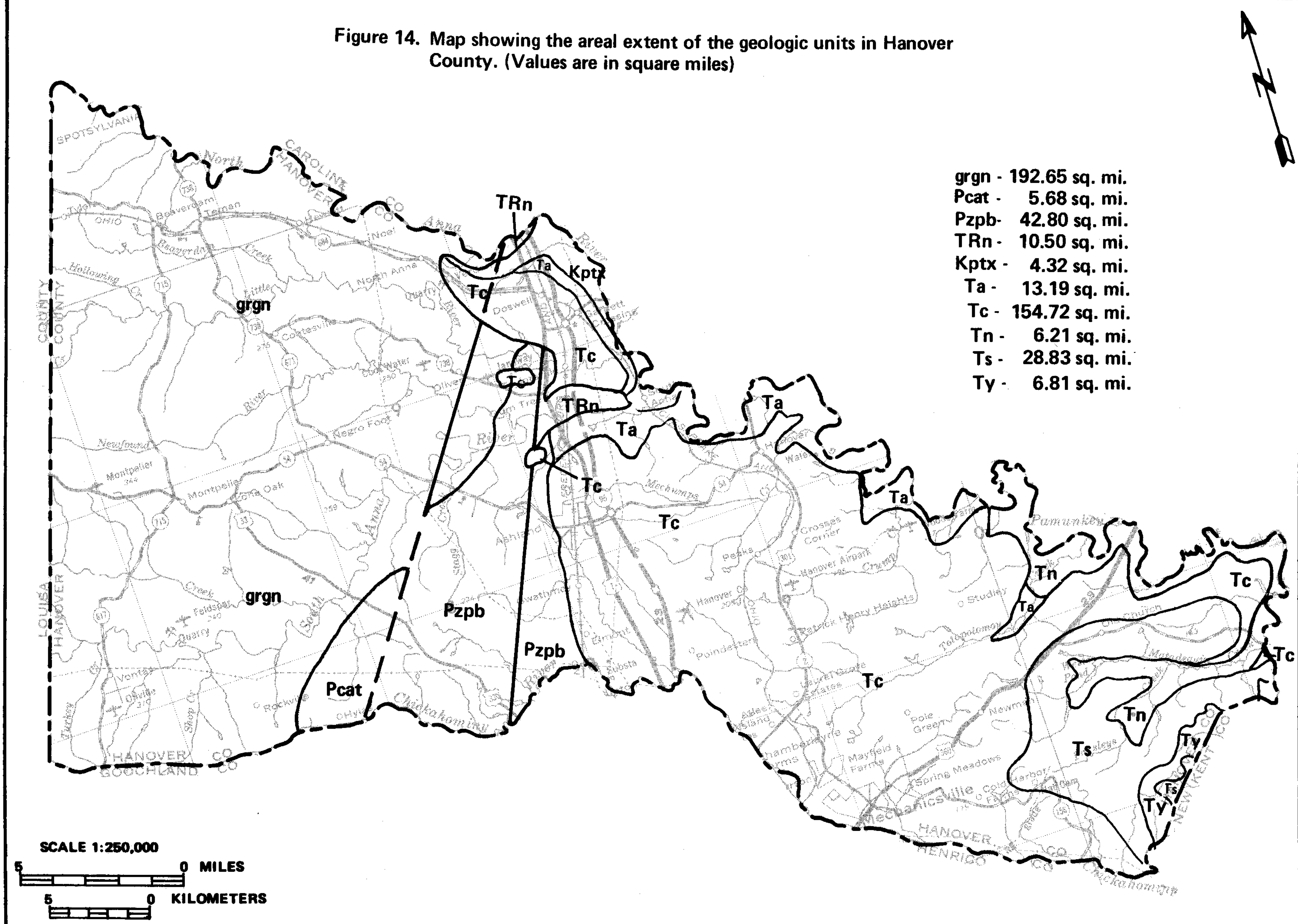
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 13. A schematic diagram showing subsurface cross-section of typical Piedmont drainageway and associated saprolite, faults, and stream alluvium.



SOURCE: STATE WATER CONTROL BOARD — PRO

Figure 14. Map showing the areal extent of the geologic units in Hanover County. (Values are in square miles)



SOURCE: GEOLOGIC MAP OF VIRGINIA (1963)

amphibolite (am). These crystalline rocks are most commonly interlayered, but two distinct areas near Hylas are dominated by biotite-rich gneiss (Goodwin, 1970).

Brown (1937) referred to the granite gneiss as the State Farm Gneiss. He described it as a Precambrian biotite-oligoclase gneiss of igneous origin. The granite gneiss is considered older than the cataclastic rocks (Pcat) (southeastern contact) and the Petersburg Granite (Pzpb) to the east because these units either intrude or superpose it. Granite gneiss dominates the Piedmont section north of the Hylas gradrangle. Goodwin (1970) described it as a relatively uniform, even-banded, well-foliated granite gneiss. Jointing is common in the gneiss and, thus, has a direct effect on potential groundwater yields. Foliation (planar arrangement of mineral grains) is well developed. Pegmatites, along with veins of quartz and granite, are noted both parallel and perpendicular to the foliation, with the largest pegmatites (three inches wide) being concordant (parallel) to the foliation.

Biotite gneiss is well exposed along the right bank of the South Anna River 0.1 mile west of where State Road 673 crosses the South Anna River. It is biotite rich and intensely foliated, approaching a schitose texture (Goodwin, 1970).

Other Precambrian units interlayered with the granite and biotite gneiss include the amphiobolite and hornblende gneiss. Foliation is parallel to the surrounding gneiss, and the units are presumed to represent metamorphosed lava flows or beds of mafic pyroclastic debris (Goodwin, 1970, p. 6).

Many fracture patterns and joint sets (no displacement fractures) exist in these rocks. The fractures and joints are the primary groundwater source and storage areas in the Piedmont rocks. A technique known as fracture-trace analysis enables delineation of fault lines and highly jointed areas. Areal photography and high quality geologic mapping assist in locating fault lines. Once delineated, these fractured and jointed areas should be investigated for groundwater. The greater the number of fractures and joints, the greater the potential for groundwater.

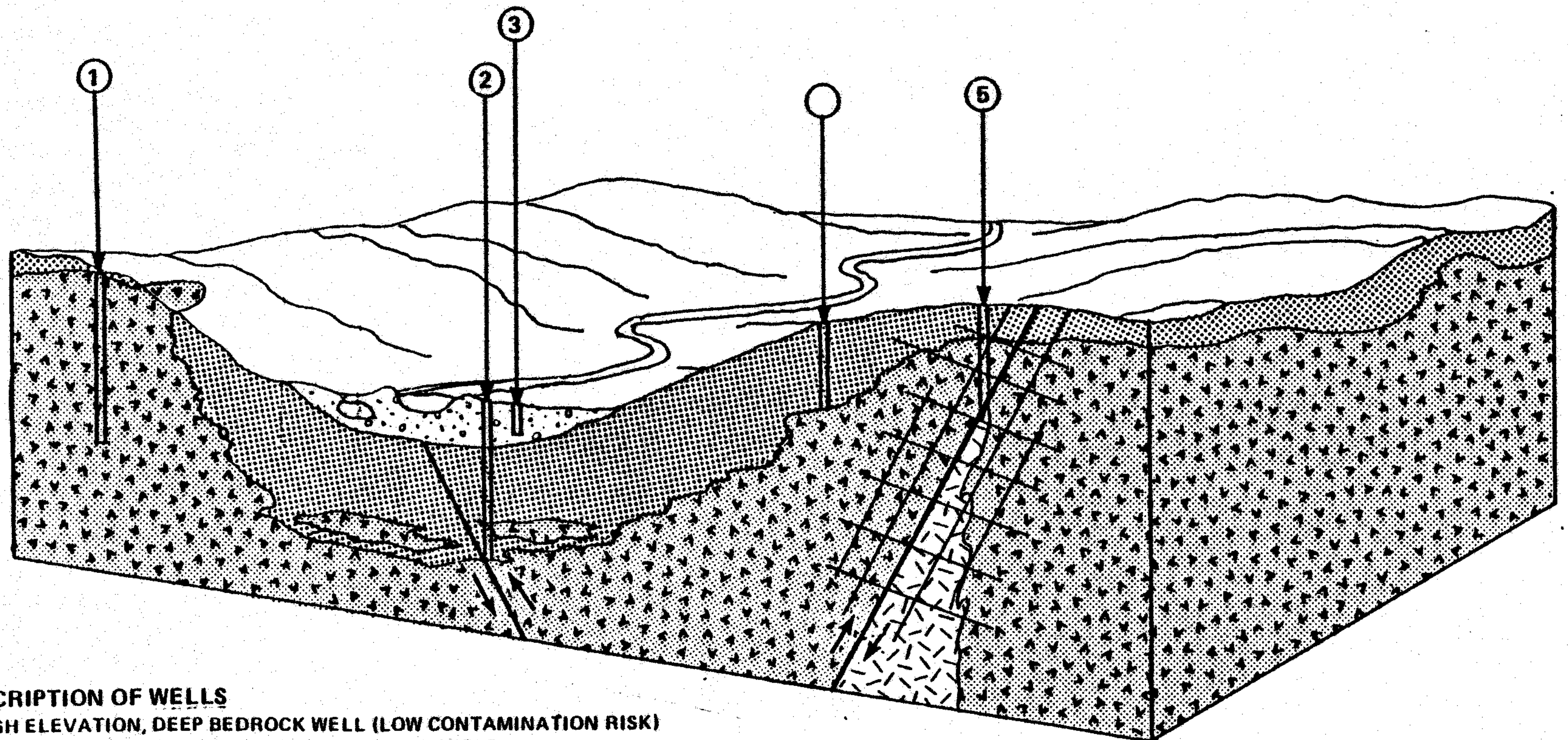
Fracture-trace analysis easily can be adapted to the Piedmont's predominately granite-like rocks. As stated earlier, these fracture zones are subject to erosion and subsequently become topographically low areas with a good potential for groundwater. It must be noted that fractures, in general, are smaller and occur less frequently with depth. Therefore, drilling a Piedmont well deeper than 300 to 400 feet is usually inadviseable unless a continuous yield increase with depth is noted.

The weathered bedrock known as saprolite is found as the surface cover for most of the Piedmont section (Figure 9). The saprolite ranges in thickness from zero feet, at a bedrock outcrop, to 100 feet (30 meters) or more in highly-weathered, topographically-low areas. The saprolite has geohydrologic characteristics similar to unconsolidated sediments, but its permeability is considerably lower due to its non-transported nature and large content of clay. Much of the infiltrating rainwater collects at the saprolite-bedrock interface due to the impermeability of the solid bedrock. Most shallow bored wells in the Piedmont tap this zone for their groundwater supply [Figure 15 (well #4)].

Stream alluvium and terrace deposits along streams and drainageways also supply some shallow wells in the Piedmont [Figure 15 (well #5)]. The unconsolidated sediments usually contain adequate groundwater supplies for domestic purposes. Most of these supplies are very susceptible to fluctuations in precipitation and nearby stream and drainageway contamination. Alluvial deposits with coarse constituents are the best potential groundwater source. Such deposits are sparce in Hanover County, but can be found in buried stream channels within a river plain (Figure 15).

Many pegmatites (Figure 9) (coarse-grained igneous dikes and veins) occur in the Piedmont and in many cases develop into highly-permeable gouge zones (fine-grained debris) due to weathering action. These pegmatitic gouge zones store groundwater and can yield adequate domestic supplies, but possible high iron concentrations and surface contamination make the majority of them less than ideal groundwater sources.

Figure 15. Typical groundwater well locations in the Piedmont.



DESCRIPTION OF WELLS

1 HIGH ELEVATION, DEEP BEDROCK WELL (LOW CONTAMINATION RISK)
- THIN SAPROLITE ∴ POOR GROUNDWATER YIELD.
- NO FRACTURE INTERSECTIONS ∴ POOR GROUNDWATER YIELD.

2 LOW ELEVATION WELL (HIGH CONTAMINATION RISK IN UPPER FORMATIONS)
- THICK STREAM ALLUVIUM AT TOP ∴ GOOD YIELD.
- THICK SAPROLITE BELOW ∴ GOOD YIELD.
- BEDROCK FRACTURE ZONE AT BOTTOM ∴ EXCELLENT YIELD.

3 LOW ELEVATION WELL (HIGH CONTAMINATION RISK)
- SHALLOW STREAM ALLUVIUM ∴ GOOD YIELD

4 HIGH ELEVATION, THICK SAPROLITE WELL TO BEDROCK (SLIGHT CONTAMINATION RISK)
- THICK SAPROLITE ∴ FAIR TO GOOD YIELD.

5 HIGH ELEVATION, SAPROLITE AND BEDROCK WELL (SLIGHT CONTAMINATION RISK)
- THICK SAPROLITE ∴ FAIR TO GOOD YIELD.
- BEDROCK FRACTURE AND JOINT INTERSECTIONS ∴ EXCELLENT GROUNDWATER YIELD.

SOURCE: STATE WATER CONTROL BOARD – PRO

The groundwater yields from the Precambrian rocks are quite variable. Faults, joints, and depth of the saprolite are very site specific (localized) and directly affect the groundwater yield. One location may yield 40 gallons per minute, while a well only a few hundred feet away can be dry. Table 4 lists the notable wells from the Precambrian granite gneiss (grgn), with their tested water yields in gallons per minute (GPM).

Although the contour map (Plate 12b) shows higher yield areas south of Montpelier and in the vicinity of Beaverdam, this must not be construed to reflect the true groundwater potential in these areas. The numbers of fractures encountered, well diameter, and the efficient development of the groundwater supply are important factors controlling the groundwater yield attained. An average yield of from 10 to 20 GPM (37.9 to 75.7 liters per minute) can be expected throughout the Precambrian rocks of Hanover County.

Precambrian Rocks - Groundwater Quality. Groundwater quality is very dependent upon the chemical composition of the surrounding rocks. The mineralogic composition of the granite and biotite gneiss includes quartz (SiO_2), potassic feldspar ($KAl\ Si_3O_8$), plagioclase feldspar [(Ca, Na) (Al, Si) $Al\ Si_2\ O_8$], biotite [$K(Mg, Fe)_3\ (Al\ Si_3O_{10})\ (OH)_2$], hornblende [$NaCa_2\ (Mg,Fe, Al)_5\ (Si, Al)_8\ O_{22}(OH)_2$], and garnet [Alamandite - $Fe_3Al_2\ (SiO_4)_3$]. Accessory minerals include sphene ($Ca\ Ti\ SiO_5$), zircon ($Zr\ SiO_4$), and apatite [$Ca_5\ (PO_4)_3$ (F, Cl, OH)]. The hornblende gneiss and amphibolite contain hornblende, plagioclase, quartz, potassic fieldspar, pyroxene [(Mg, Fe) SiO_3], sphene, apatite, and calcite ($Ca\ CO_3$). These minerals provide the chemical constituents that naturally influence groundwater quality. The slow percolation of water into the ground allows intimate and long contact of the water with the surrounding minerals. Because these minerals are soluble to a greater or lesser degree, the groundwater will increase in mineral content as it percolates through the subsurface until an equilibrium or balance of dissolved substances is reached. It should be noted that many variables affect groundwater quality, but mineralogy is one of the more significant.

Table 4. Data on Water Wells Located in the Granite Gneiss of the Piedmont Section

SWCB Well Number	Yield (GPM)	Liters Per Minute (LPM)	Depth of Water Zone
22	10	37.8	220-221', 238-240' (67-67.4M; 72.5)
24	10	37.8	89-90' (27.1-27.4M)
31	1	3.8	22-200' (occasional fractures) (6.7-61M) (25-25.3M) (11.4LPM) (40.9-41.4M) (26.5 LPM)
34	40	151.4	82-83' (3 GPM), 134-135' (7 GPM), 151-152' (46-46.3M) (fracture at 151-152' with 30 GPM) (113.6 LPM)
35	1	3.8	70-207' (occasional fractures) (21.3-63.1M)
36	20	75.7	25-82' (occasional fractures) (7.6-25M)
82	7	26.5	72-320' (occasional fractures) (21.9-97.5M)

In geńeral, groundwater quality from the Precambrian rocks is good. There are isolated cases, however, where groundwater quality can be jeopordized. These cases involve areas in which fracture zones lack a saprolite cover which acts as a "water filter." Pegmatite zones have groundwater quality characteristics and problems similar to joint and fracture zones.

The quality of saprolite-derived groundwater is usually quite good due to adequate filtration. Due to the shallowness of wells developed in saprolite, however, the chance of surface contamination is a continual threat to their quality.

Stream alluvium and terrace deposits are good groundwater purifiers and source areas, but usually they are not of sufficient size and extent to be dependable producers in Hanover County. In shallow gravel deposits (ancient stream channels of high porosity and permeability), the water is not renovated (purified by percolation) as rapidly as in finer grained materials. Occasionally, ancient buried stream channels can provide adequately purified groundwater in large volumes. Surface contamination from floods remains the biggest threat to a well which taps stream alluvial deposits.

Groundwater is notably soft in the Precambrian rocks with very few soluble Ca, Mg ions found in the granite gneisses. Specific conductance is very low, indicating few dissolved solids. The pH ranges from 4 to 7; the majority of the groundwater averages about 6. Low iron concentrations of 0.05 to 0.10 ppm are common in the Precambrian rocks, but chloride and fluoride concentrations are very acceptable. Nitrate concentrations are very low in the Precambrian rocks except near Beaverdam where slightly higher values are noted. Contamination by septic tanks and animal wastes could be influencing these values.

Paleozoic Rocks (600 to 230 million years old). The rocks of Paleozoic age include the cataclastic rocks (Pcat), called metavolcanics by other authors, and the Petersburg Granite (Pzpb) (Figure 6).

The cataclastic rocks occupy an area of approximately 5.68 square miles and lie in the south-central portion of the County (Figures 6 and 14). They are bordered on the west by amphibolite and the granite, biotite, and hornblende gneisses, and on the east by the younger Petersburg Granite. The major minerals found in these rocks include: quartz, potassic feldspar, plagioclase, and muscovite (sericite).

The cataclastic rocks are highly jointed gneisses that have a noteworthy cataclastic texture indicating great mechanical stress and deformation. The many joints and fractures all along the eastern edge of the cataclastic unit are a result of the great shearing forces that occurred. This fault-shear zone is in line with the Triassic faults to the southwest (Richmond Triassic Basin) and northeast. The fault and its associated, highly-fractured zones have a good groundwater potential.

The Petersburg Granite (Pzpb) lies to the east of the cataclastics in a triangular-shaped area with corners located southwest of Doswell, east of Hylas, and just west of Elmont (Figure 6). Its areal extent is approximately 42.8 square miles with the Fall Zone as its eastern border (Figure 14). As classified by Bloomer (1939, p. 142-143), the Petersburg Granite consists of three phases: a gray to pink, medium-grained granite; a blue, relatively fine-grained facies; and a porphyritic facies. An average compositional analysis of the granite is 38 percent orthoclase, 35 percent plagioclase, 25 percent quartz, and 2 percent mafic minerals.

The Petersburg Granite borders the cataclastic rocks east of the fault zone. There is another fault zone extending in a northeast-southwest direction through the central portion of the granite unit. This second fault zone is also a good potential source for groundwater. The onlapped Coastal Plain sediments form the eastern border of the granite.

The predominant source of groundwater, however, for both the cataclastic and Petersburg Granite areas, is the saprolite associated with these two units. The saprolite generally yields good quality water in sufficient amounts to satisfy domestic needs.

In general, the Paleozoic rocks, saprolite included, have groundwater yields ranging from 1 to 50 gpm (3.8 to 189.2 liters per minute); a yield of 10 gpm (37.9 liters per minute) is the average for these rock units.

Paleozoic Rocks - Groundwater Quality. The groundwater quality of the cataclastic rocks and the Petersburg Granite is very similar to that encountered in the Precambrian rocks. The same effects of fractures, pegmatites, saprolite, and alluvium are noted in these Paleozoic rocks.

Hardness values are soft to moderately hard. Specific conductance and total dissolved solids increase in the Petersburg Granite, with the highest values along the eastern border (Fall Zone). The pH fluctuates from 5.0 to 9.0. Iron values range from 0.05 to 1.0 ppm in both the cataclastics and Petersburg Granite. Chloride ranges from 1.0 to 10.00 ppm, with fluoride ranging from 0.5 to 1.0 ppm. Nitrate concentrations are from 0.5 to 10.0 ppm in both units.

Triassic Rocks (230 to 180 million years old). The Triassic rocks are the youngest rocks of the Piedmont and are confined to areas known as the Triassic basins. Total areal extent of the Triassic age rocks in Hanover County is 10.50 square miles (Figure 14). Normal faulting occurred early in Triassic time, creating basins which were filled subsequently with detrital sediments transported from the west. Figure 8 is a schematic representation of a typical Triassic basin.

Triassic basins are found throughout the Piedmont Province of Virginia. Common, well-consolidated, sedimentary units noted within a typical Piedmont Triassic Basin include: coal (not noted in Hanover County), coarse conglomerates, shales, and interbedded shales and sandstones. The majority of the Triassic rocks usually are referred to as "red beds" (shales and sandstones) due to their characteristic red color (iron oxide staining). Such rocks have been noted under hundreds of feet of Coastal Plain sediments further to the east (Teifke, 1973, well #3316).

In Hanover County, diabase dikes cut through the Triassic sedimentary rocks near Hylas and continue into the cataclastics (Goodwin, 1970, p. 5). Coal has not been noted in Hanover County's Triassic basins, but exists in the Richmond Basin to the north. Shales and sandstones are the major rock types in the Triassic basins in Hanover County.

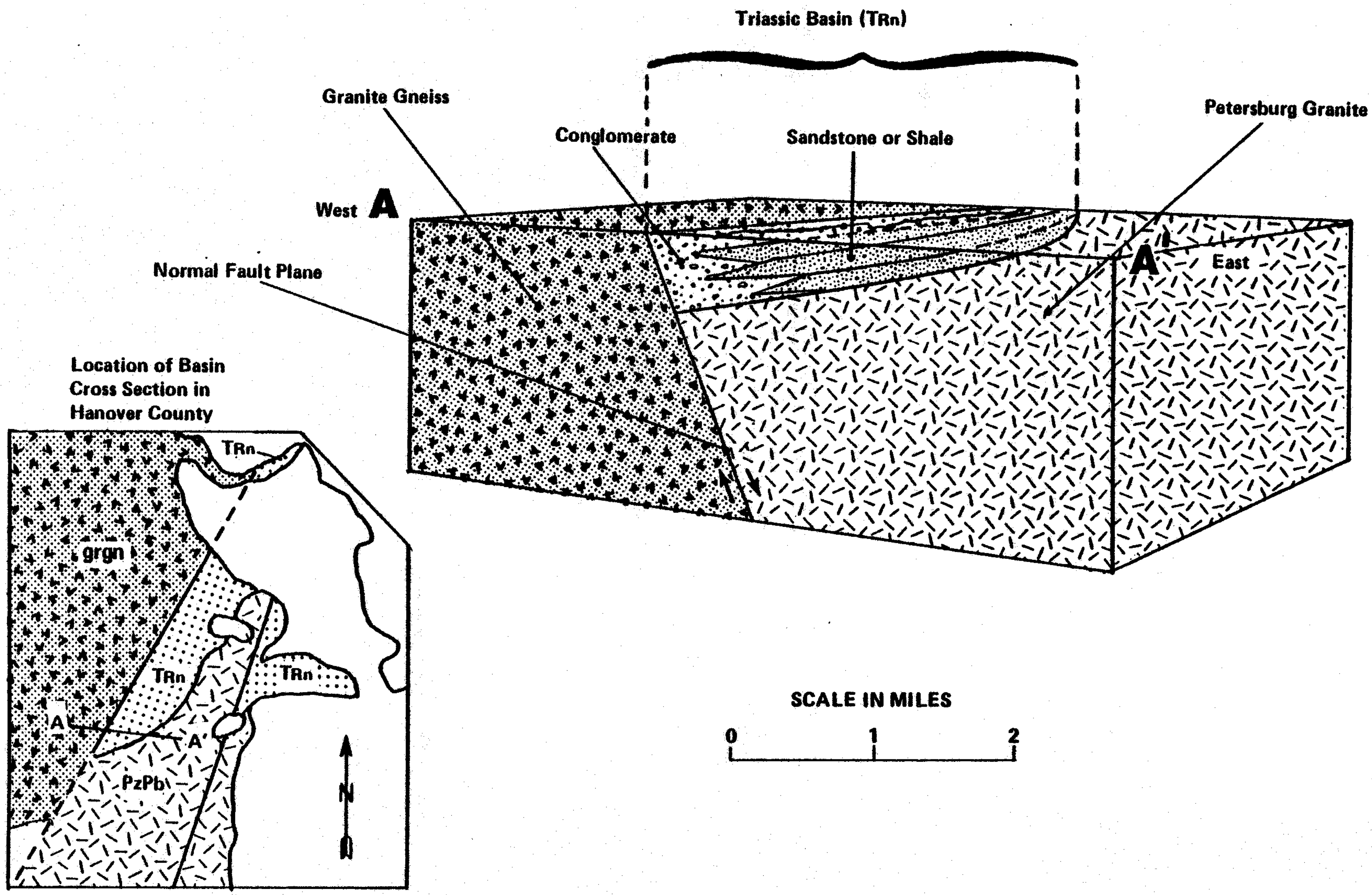
The Triassic ($T_{R}n$) basin rocks have geohydrologic properties similar to the nearby Petersburg Granite and Precambrian granite gneiss. These well-consolidated Triassic sediments were deposited in down-faulted basin areas, with the coarser materials deposited along the faulted western margins. The finer-grained materials were deposited in the eastern portion of the basins (Figure 16). The greatest groundwater potential within the Triassic basin rocks is along the western border where faults, conglomerates, and the greatest thickness of basin fill are located. Triassic groundwater yields are generally lower than those from unconsolidated sediments of equal grain size and similar composition. This characteristic is due to the decreased porosity and permeability of the Triassic Rocks caused by their consolidation (intergranular cementation).

Table 5 lists major wells located in the Triassic rocks with their tested yields and water zone data.

The contour map showing yield indicates highest groundwater yields north of Doswell near the Hanover-Caroline County Line (Figure 12b). Yields differ greatly throughout the Triassic basins from 4 to 165 GPM (15.1 to 624.6 liters per minute) with most of the wells yielding from 5 to 40 GPM (18.9 to 151.4 liters per minute).

<u>Triassic Rocks - Groundwater Quality</u>. Groundwater quality from the Triassic basins is similar to that of the Petersburg Granite and of the Precambrian granite gneiss. Total hardness is usually about 60 ppm, with the Ca, Mg hardness being very similar. Specific conductance ranges from 100 to 300 micro-mhos/cm, and the pH ranges from 5 to 7. Iron concentrations are from 0.05 to 0.1 ppm, with total dissolved solids from 100 to 200 ppm. Chloride commonly ranges from 1 to 10 ppm in the Triassic, and fluoride concentrations of 0.05 to 1.0 ppm are noted. Nitrate ranges from less than 0.5 ppm in the western portions of the Triassic basins to 5 ppm in the east.

Figure 16. Schematic diagram showing a typical Triassic basin cross-section.



SOURCE: STATE WATER CONTROL BOARD – PRO

Table 5. Triassic Rock Well Data.

SWCB Well Number	Yield (GPM)	Liters Per Minute	Depth of Water Zones (feet) (meters)
20	5	18.9	100-200' (30.5-61M)
21	30	113.6	59-120' (18-36.6M)
30	40	151.4	46-107' (14-32.6M)
45	12	45.4	41-150' (12.5-45.7M)
46	20	75.7	76-155' (23.2-47.2M)
48	4	15.1	45-145' (13.7-44.2M)
129	118	446.7	50-55', 103-109' (15.2-16.8M; 31.4-33.2M)
131	165	624.5	55-60' (8 GPM), 60-76' (12 GPM), 80-86' (24.4-26.2M) 30 GPM (113.6 lpm), 165' (50.3M) (Fracture encountered) 115 GPM (435.3 lpm)
180	10	37.9	50-287' (15.2-87.5M)

The Fall Zone

The border zone between the Piedmont rocks to the west and the Coastal Plain sediments to the east is the Fall Zone (Figure 4). In Hanover County this zone trends north-south, parallel to, and in the vicinity of Interstate Route 95. An abrupt fall in land elevation is noted in the Fall Zone. This difference in elevation is displayed not only in the topography but also by the change in velocities of the streams and rivers and by the many Petersburg Granite outcrops.

Sources for groundwater in the Fall Zone are rather limited and include the saprolite overlying the Petersburg Granite; the thin, onlapping, undifferentiated, Coastal Plain sediments; and the underlying Petersburg Granite bedrock. The best source of groundwater in the Fall Zone is from the deeper, underlying Petersburg Granite. Fractures and joints in the granite offer a greater potential for better groundwater quality and quantity than the saprolite and unconsolidated materials (Figure 17).

Coastal Plain Geohydrology

The major groundwater production aquifers in the Coastal Plain section of Hanover County include the Paleozoic and Triassic ("basement complex") rocks, the principal artesian aquifer (Cretaceous: Patuxent Formation), upper artesian aquifer (Late Cretaceous and Tertiary), and the near-surface water table aquifers. (An artesian aquifer is a geologic unit capable of yielding groundwater under a hydrostatic pressure due to confinement both above and below by less-permeable rock units.) Table 3 summarizes the aquifers and their water bearing characteristics.

Paleozoic "Basement Complex" (600 to 230 million years old). The major unit of the "basement complex" in the Coastal Plain part of Hanover County is the granitic bedrock and its derived saprolite, although some Triassic "red beds" have been encountered. The unweathered granite is similar to that found to the west in Piedmont exposures and has similar geohydrologic characteristics. Granite outcrops are rare

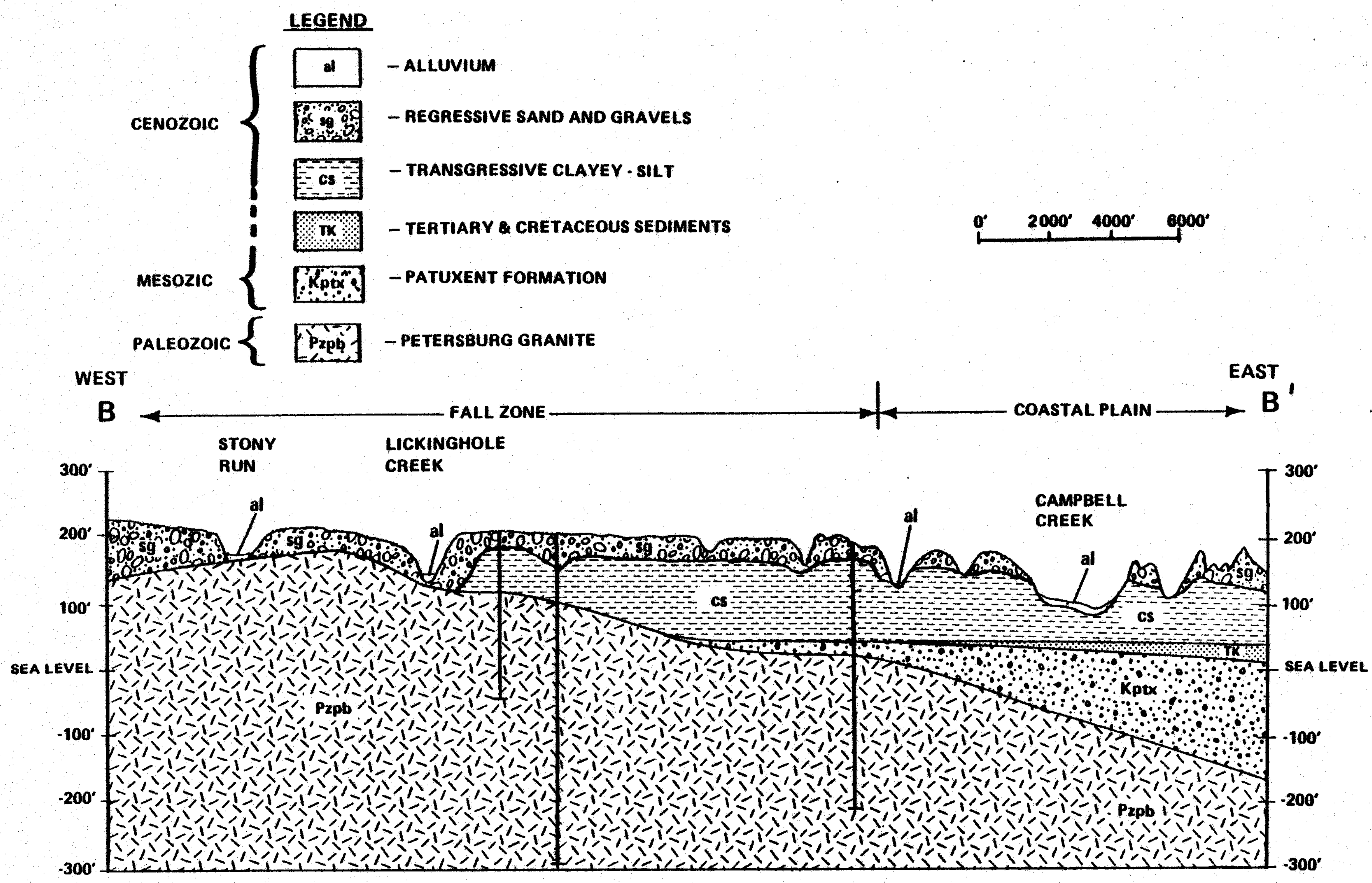


Figure 17. Interpretive cross-section showing portions of the Fall Zone and Coastal Plain section.

SOURCE: DANIELS, ONUSCHAK (1974)

in the Coastal Plain and mainly occur along drainageways near the Fall Zone (Figure 7a), where the washing away of thin Coastal Plain deposits has allowed their exposure.

The saprolite is usually red,clayey, medium- to coarse-grained sand of variable thickness overlying the bedrock. In its most weathered form it may contain no identifiable structures and, therefore, is very difficult to distinguish from some regressive sediments that have been transported for only a short distance ("granite wash"). The reworked saprolite is interpreted as a major source from which the Coastal Plain sediments were derived (Daniels and Onuschak, 1974, p. 14).

Subsurface samples obtained from State Water Control Board well #142-2 (VDMR 3904) in eastern Hanover County indicate that the Triassic may have been encountered at 344 feet below sea level. These samples are predominately mudstone and sandstone. The mudstone appears to have some minor cementation and variation in the lithic composition. Sorting is very poor, yielding a low order to textural maturity (Folk, 1965, p. 102). Clay layers found in the Triassic rock are commonly yellow, purple, gray, and green in color.

The geohydrology and groundwater quality characteristics of these rocks are presumed to be similar to the Precambrian, Paleozoic, and Triassic rocks in the Piedmont portion of the County.

Cretaceous Period (135 to 63 million years old). The lowest Cretaceous unit is the Patuxent Formation (Kptx). The surface areal exposure of this formation in Hanover County is approximately 4.32 square miles (Figure 14). The Patuxent lies unconformably on the "basement complex", with its top unconformably overlain by Late Cretaceous age rocks. These Patuxent regressive, fluvial deposits were laid down in a wedge-shaped formation that increases in thickness eastward.

The characteristic, regressive, coarse sands and gravels, coupled with the great thickness and extent of the formation, provide for vast storage and production of groundwater. From the Fall Zone where it outcrops, the Patuxent dips eastward, increasing in thickness to 550 feet (167.6 meters) near the eastern border of Hanover County, where it is encountered at some 200 feet (61 meters) beneath the surface. D. J. Cederstrom (1957, p. 8) comments that:

> "Near the Fall Zone, Cretaceous units in the aggregate are thin, and permeable sand beds may be thin or lacking. It is thought that the part of Hanover County lying east of a north-south line drawn through Hanover Courthouse and Mechanicsville is favorable for the development of large supplies of water from deep wells, and that the easternmost part of the County is particularly favorable."

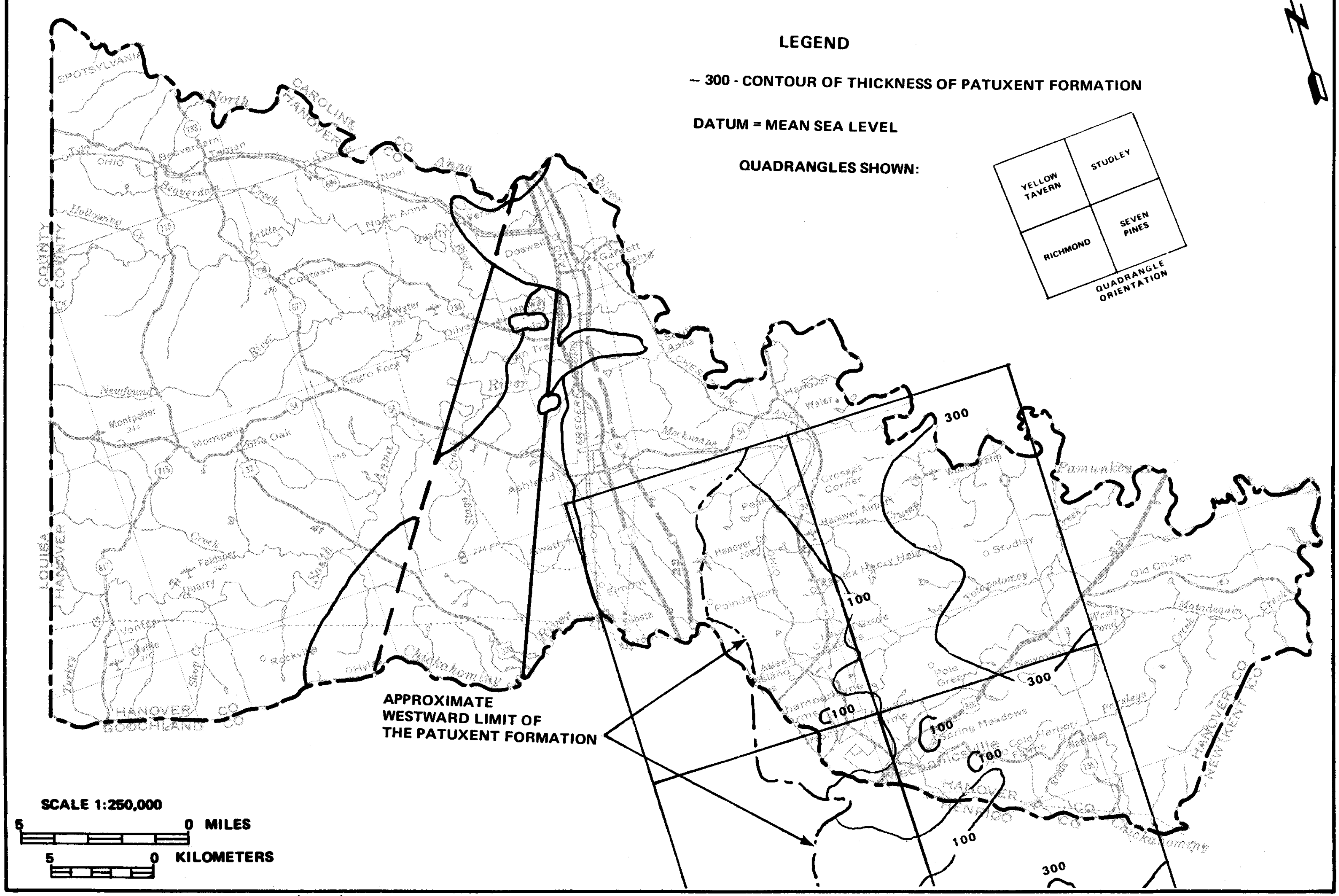
Figure 18a shows the geologic interpretation of Patuxent occurrence and thicknesses by Daniels and Onuschak (1974). Figures 18b and 18c contain the Patuxent Units H and F as interpreted by Brown (1972). Both interpretations are provided in order to present the most recent interpretations of Patuxent subsurface delineation. It should be noted that Figure 18a is based on quadrangle data, whereas Figure 18b and 18c are from regional data (implying that Figure 18a is more accurate because of greater detail in study).

The progradational deltas (Figures 19a and 19b) of the Patuxent Formation have definite areas of coarse and fine sediment deposition. The high energy regimes of the distributary channels deposited coarse sediments into "basement complex" topographic lows (Figure 5a and 5b). As the basement lows filled, finer-grained sediments were deposited on the flanks of the basement highs. Differential compaction of these sediments, brought on by the weight of subsequent deposition, has caused the fine-grained deposits to become thinner (subsidence) than the coarser deposits. Thus, basement highs eventually became the location for later depositional activity. This process is more fully developed in VDMR Report of Investigations #38 and will be developed further in this report as an aid to aquifer delineation.

In order to better understand the water-bearing characteristics of the principal artesian aquifer (Patuxent Formation), the yields, static water levels, drawdowns, sand percentages, specific capacities, and hydraulic conductivities (average permeability) must be studied.

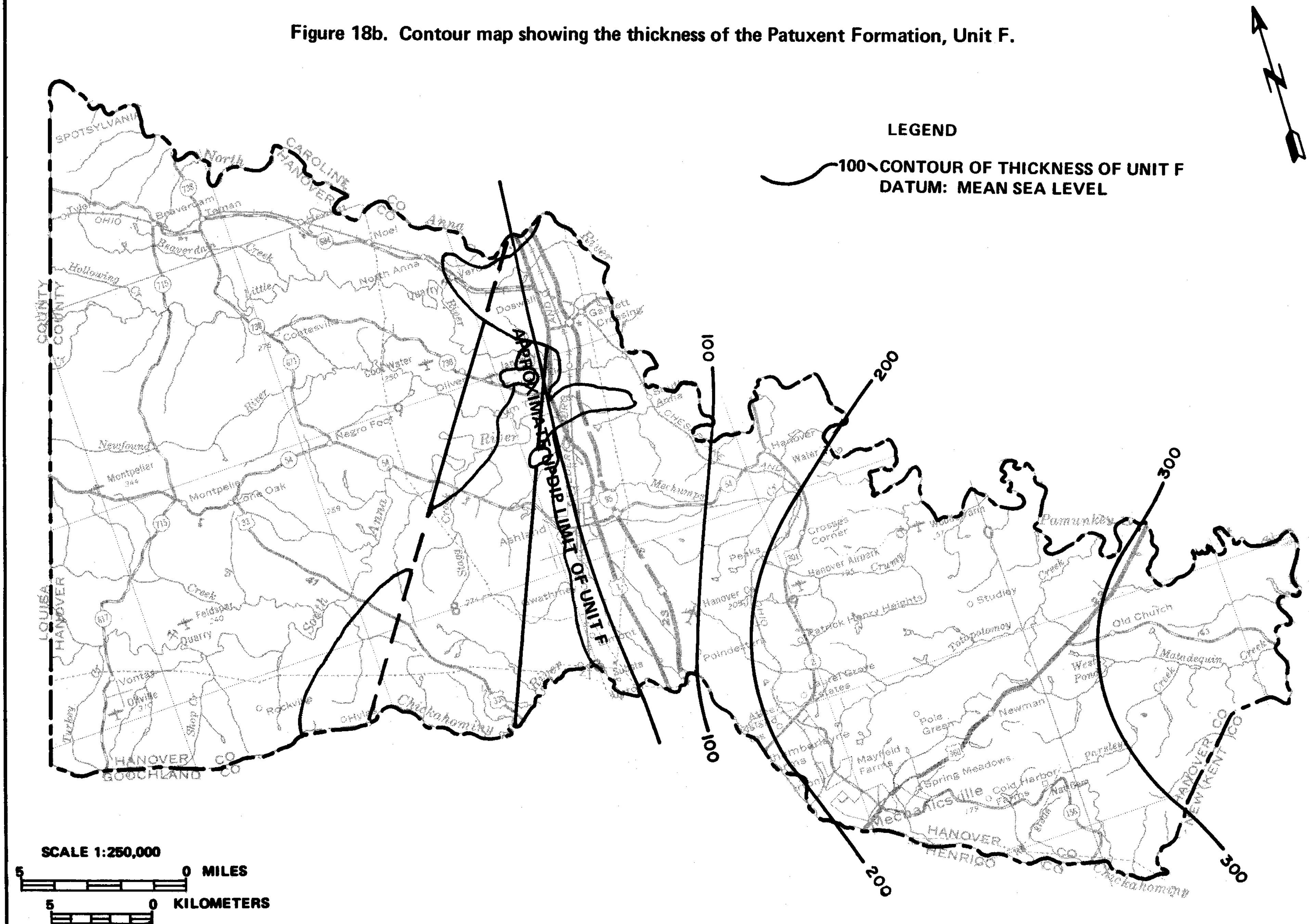
The Patuxent Formation in Hanover County has groundwater yields that range from 8 GPM (30.3 liters per minute) at well #422 to 178 GPM (673.8 liters per minute) at well #7 (Table 6). These yield values can be correlated when the length of the screened section (water intake), the position of the screens in the aquifer, the size

Figure 18a. Contour map showing the thickness of the Patuxent Formation.



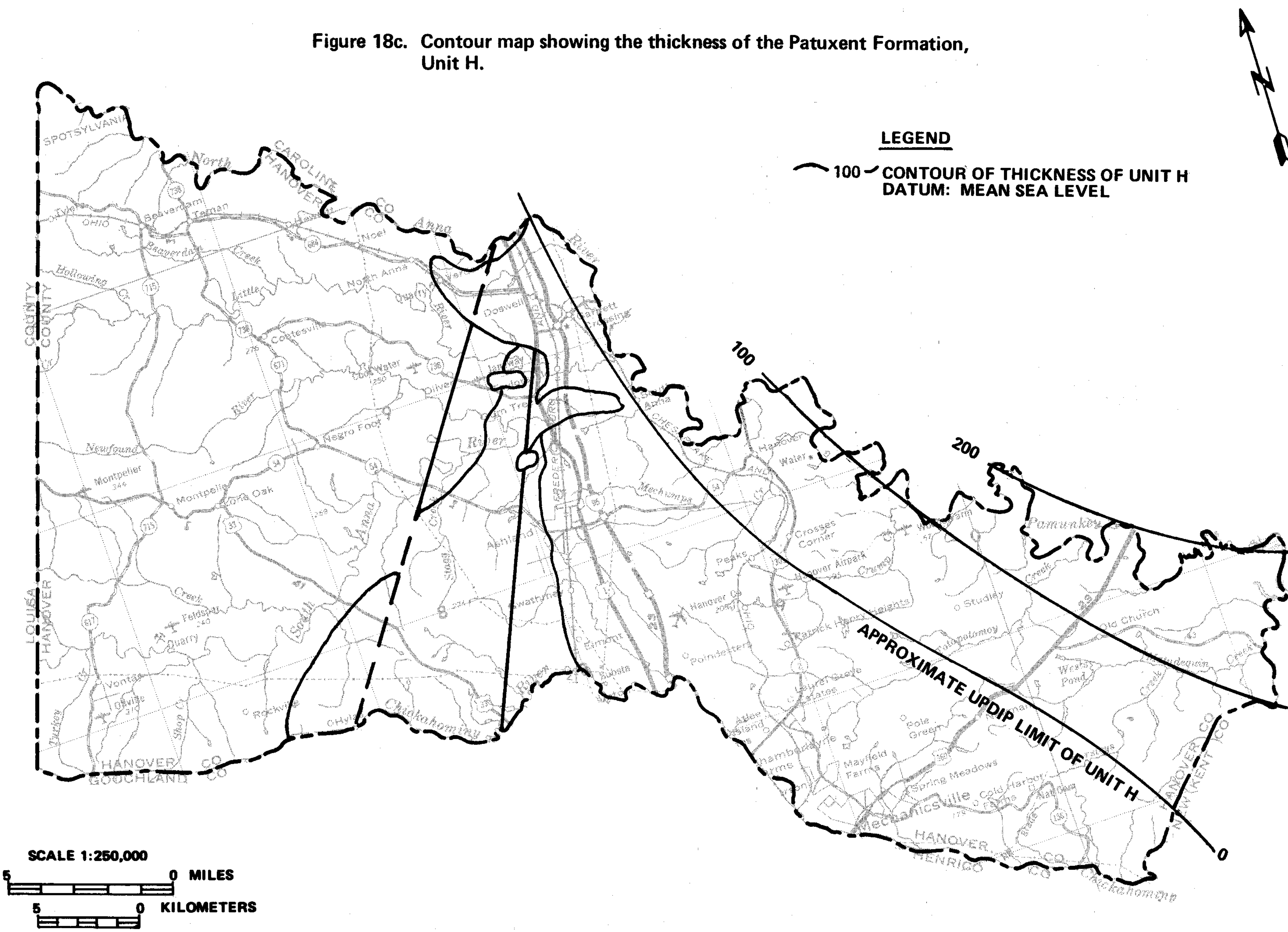
SOURCE: DANIELS & ONUSCHAK, (1974)

Figure 18b. Contour map showing the thickness of the Patuxent Formation, Unit F.



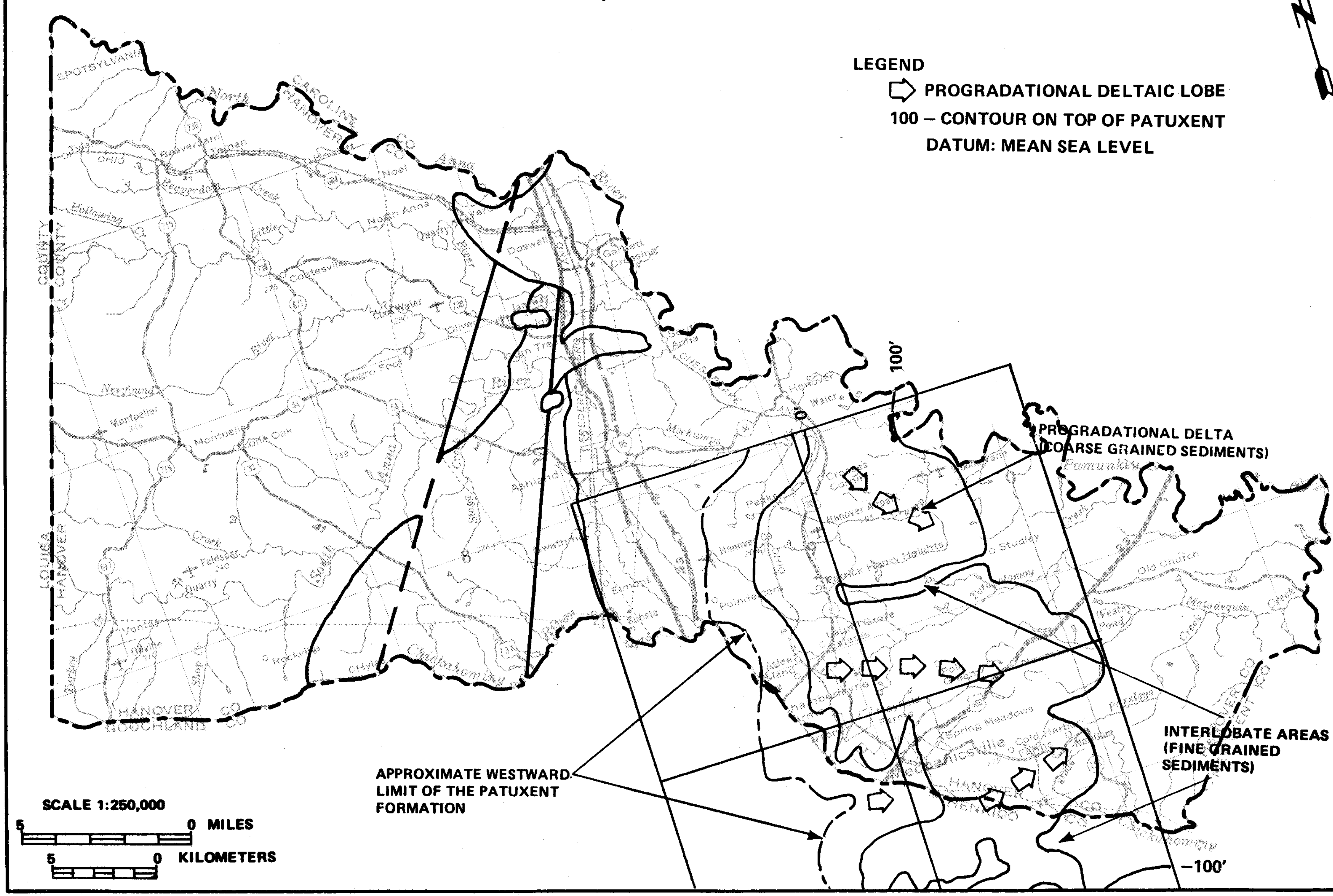
SOURCE: BROWN, MILLER, AND FREDERICK (1972).

Figure 18c. Contour map showing the thickness of the Patuxent Formation, Unit H.



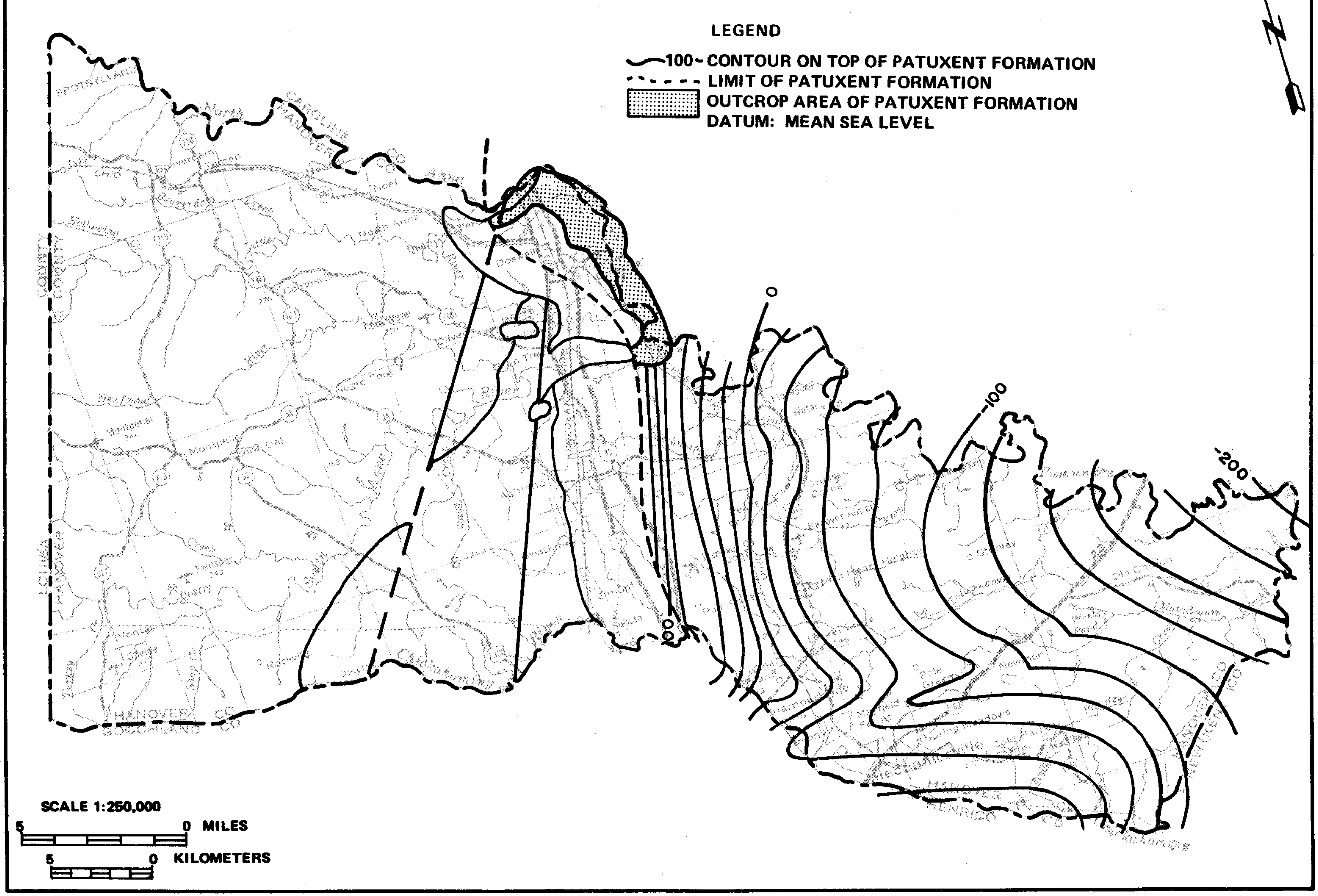
SOURCE: BROWN, MILLER, AND FREDERICK (1972)

Figure 19a. Structure-contour map of the Patuxent Formation showing progradational delta lobes with contours on top of the Patuxent.



SOURCE: DANIELS & ONUSCHAK (1974)

Figure 19b. Structure contour map of the Patuxent Formation.



SOURCE: TIEFKE, 1973.

TABLE 6. GROUNDWATER INFORMATION FROM

PATUXENT FORMATION WELLS

SWCB Well Number	Specific Capacity (GPM/FT)	Thickness of Aquifer Screened	Drawdown (ft)	Yield (GPM)	Hole Diameter
1	0.21	20'	79'	17	0.5'
2	1.66	25'	42'	70	1.0'
3	0.83	20'	98'	82	0.833'
5	0.26	15'	75'	20	0.833'
6	0.40	43'	74'	30	0.833'
7	2.65	40'	67'	178	0.833'
8	0.56	40'	55'	31	0.833'
10	0.25	40'	83'	21	0.833'
12	0.07	30'	190'	14	1.0'
13	1.23	50'	69'	85	0.833'
14	0.55	30'	36'	20	0.833'
15	2.00	50'	60'	120	1.0'
19	1.61	15'	70'	113	0.5'
37	0.58	25'	72'	42	1.0'
38	2.54	39'	31'	79	1.0'
49		20'	73'	120	0.833'
61		10'	126'	75	0.5'
70		20'	80'	102	0.5'
74	2.87	15'	16'	46	0.66'
104		10'	24'	50	0.5'
119	0.35	100'	170'	60	1.0'
127		5'	33'	50	0.5'
130		5'	51'	30	0.5'
131		20'	80'	165	0.5'
151		30'	115'	175	0.5'
153		35'	114'	115	1.0'
160		40'	33'	82	1.0'
164	4.07	40'	27'	110	1.0'
165	1.88	40'	53'	100	1.0'

Table 6 Continued

SWCB Well Number	Specific Capacity (GPM/FT)	Thickness of Aquifer Screened	Drawdown (ft)	Yield (GPM)	Hole Diameter
166		30'	60'	38	1.0'
168		30'	105'	100	0.66'
171		40'	56'	110	0.66'
182	1.26	20'	87'	110	0.66'
186		12'	70'	15	0.5'
197		50'	21'	108	0.916'
198		100'	82'	52	1.0'
201	1.08	20'	64'	69	0.5'
206		20'	24'	41	0.5'
207		45'	105'	22	0.833'
209		20'	48'	150	1.0'
210		30'	39'	105	1.0'
217		17'	116'	65	0.666'
219		45'	36'	100	1.0'
220		30'	43'	95	1.0'
227		30'	35'	100	1.0'
230		40'	16'	80	1.0'
279		70'	16'	40	1.0'
322		30'	101'	80	1.0'
412		16'	90'	120	1.0'
414		20'	16'	47	1.0'
418	1.52	35'	36'	55	1.0'
419		15'	42'	45	1.0'
422		40'	82'	8	0.916'

of the pump, and the diameter of the hole are taken into account. When these water well variables are equated, the true groundwater potential of the aquifer can be understood. The complexities of this procedure necessitate the use of other methods of determining well productivity. Specific capacity (GPM/foot of drawdown) and hydraulic conductivity (the average permeability of the aquifer) are such methods for understanding the true groundwater potential of the aquifer.

The specific capacity of the well is obtained by dividing the yield by the measured drawdown (Figure 20a). This value then must be modified by the variables of well radius and the portion of the aquifer being used (Partial Penetration Chart, Figure 20b and 20c). Well radius data can be obtained easily. The portion, or percentage, of the aquifer being used can be determined by driller's logs and geologic data. In order to be able to use the Partial Penetration Chart, the thickness of the aquifer (m) must be known, along with the well radius (r), and the thickness of the screened portion of the aquifer. The percent of maximum specific capacity attainable can then be determined from the chart, with the maximum specific capacity of a fully-penetrating well being a good indicator of the aquifer's production potential (Table 7). High specific capacity values for an aquifer indicate a greater groundwater potential.

For example, in Figure 21, Patuxent wells and the aquifer's maximum specific capacities are superimposed upon the progradational deltaic lobes noted in the subsurface. The arrows indicate high energy areas (deltas and channels), with characteristic coarse sands and gravels which are highly porous and permeable. The interlobate areas contain fine sands, silts, and clays which are porous, but not very permeable. Figure 21 indicates high specific capacity values in the progradational deltaic lobes. A scarcity of deep wells in the interlobate areas indirectly supports the theory that these areas, in the past, have not been favored as well sites because of low groundwater yields.

The hydraulic conductivity (average permeability) of the Patuxent aquifer can be determined by properly interpreting the well data. Hydraulic conductivity is measured in Meinzers (gallons per day per square

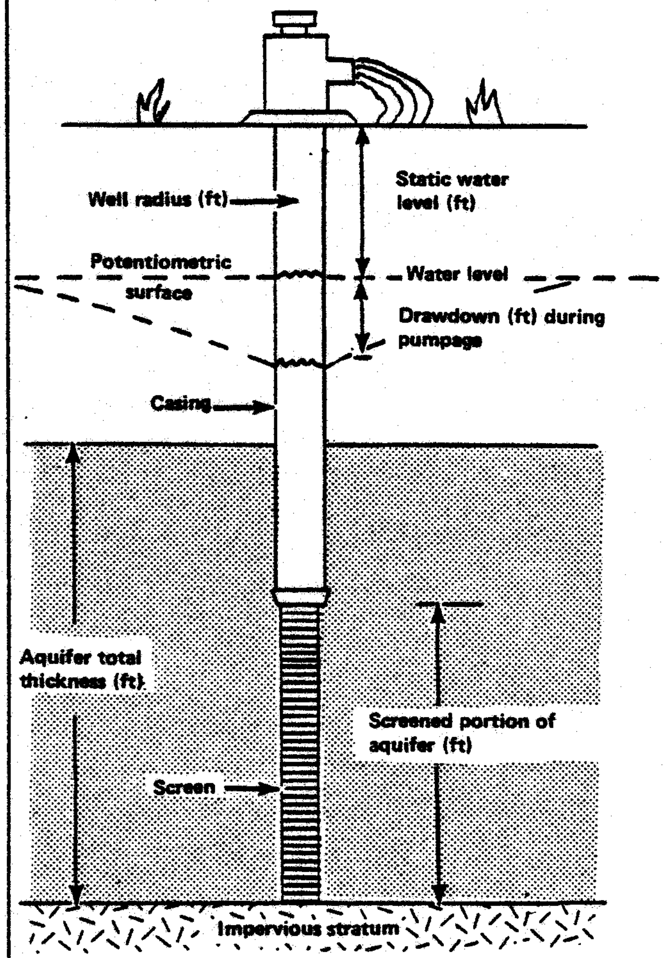


Figure 20a. Schematic showing various data needed for specific capacity determination.

SOURCE: STATE WATER CONTROL BOARD — PRO.

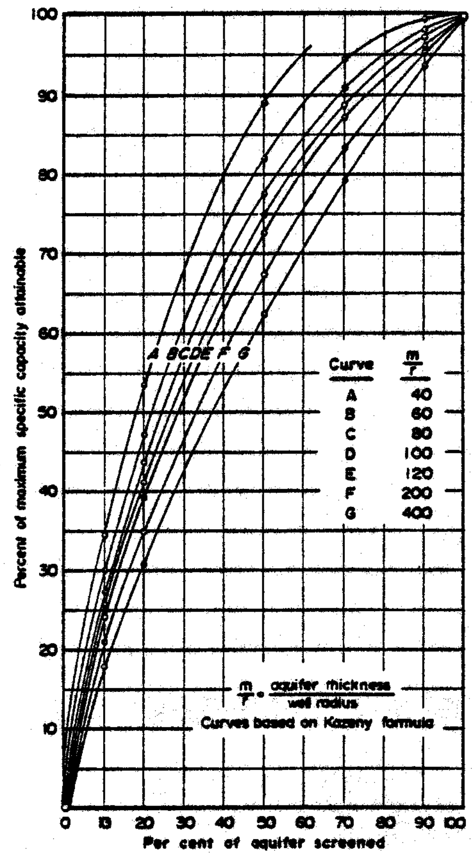
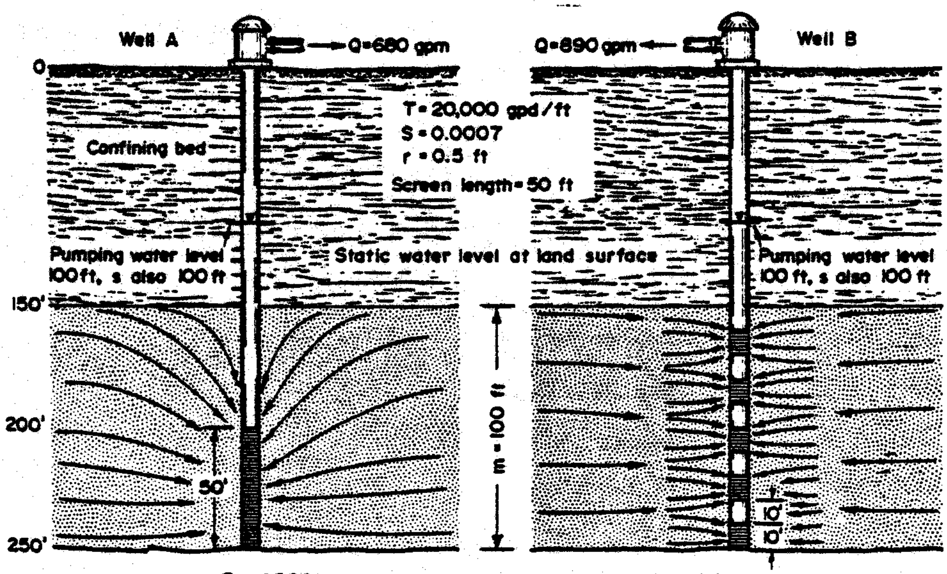


Figure 20b. Relationship of partial penetration and attainable specific capacity for wells in homogeneous artesian aquifers.

SOURCE: E. E. JOHNSON, 1974.



Q = 1000 gpm at s = 100 ft. if screen length is 100 ft.

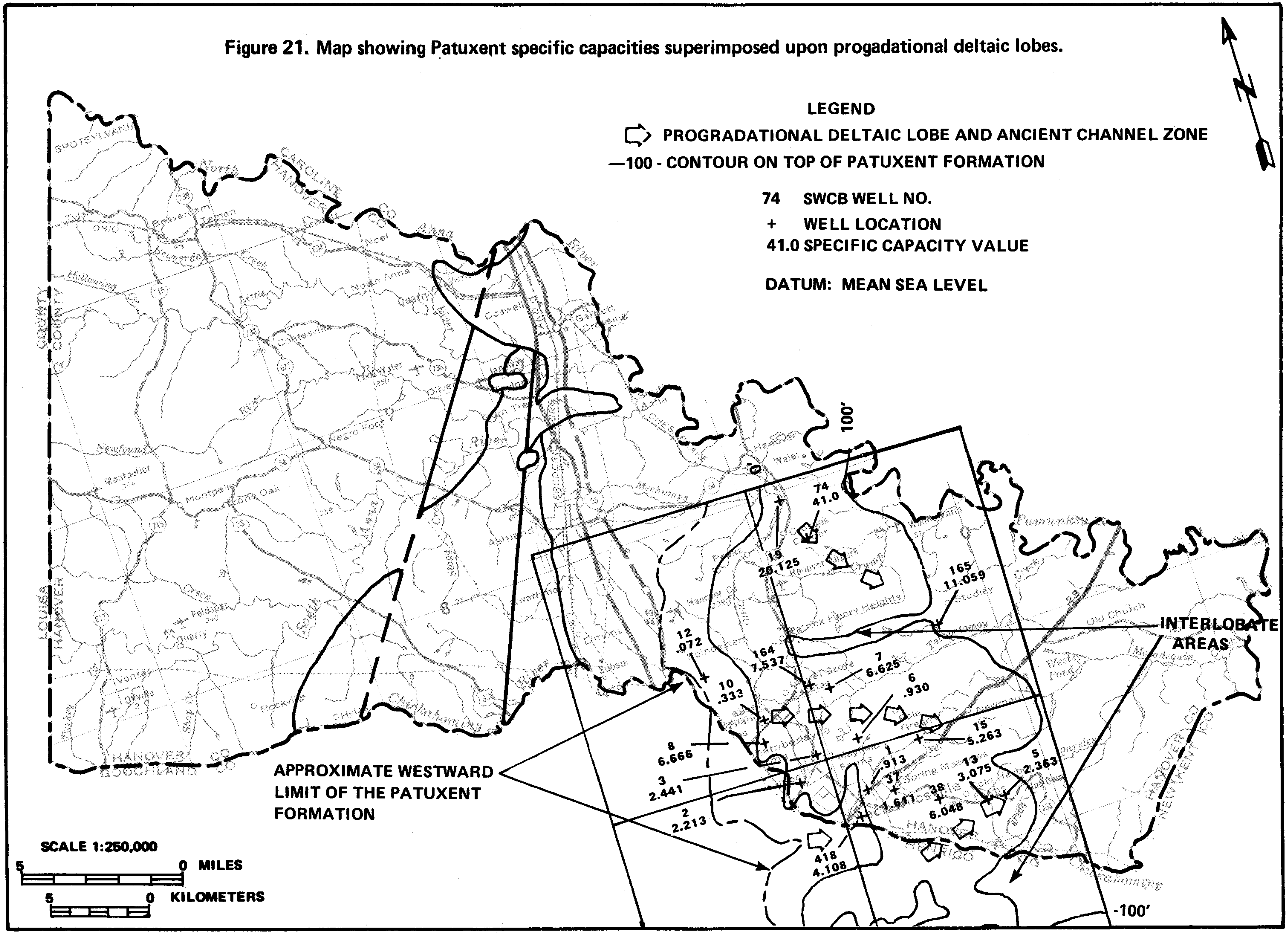
Figure 20c. Effect of Partial Penetration avoided by use of multiple screens.

SOURCE: E. E. JOHNSON, 1974.

Table 7. Patuxent Well Data for Specific Capacity Determination

SWCB Well #	Screen Thickness (in feet)	Aquifer Thickness (in feet) (m)	Well Radius (in feet) (r)	m/r	% of Aquifer Screened (Screen Thickness/ Aquifer Thickness)	Well Specific Capacity (GPM/FT) (Yield/Drawdown)	% of Specific Capacity Attainable (From Fig. 8)	Aquifer Specific Capacity from a Full Penetrating Well (GPM/FT)
1	20'	120	.240	480	16.6	0.21	23%	0.913
2	25'	50	.500	100	50.0	1.66	75%	2.213
3	20'	110	.416	264	18.2	0.83	34%	2.441
5	15'	200	.416	480	7.5	0.26	11%	2.363
6	43'	150	.416	360	29.0	0.40	43%	0.930
7	40'	150	.416	360	26.0	2.65	40%	6.625
8	40'	60	.416	144	66.0	0.56	84%	6.666
10	40'	70	.416	168	57.0	0.25	75%	0.333
12	30'	35	.500	70	86.0	0.07	97%	0.072
13	50'	180	.416	432	28.0	1.23	40%	3.075
15	50'	200	.500	400	25.0	2.00	38%	5.263
19	15'	200	.250	800	7.5	1.61	8%	20.125
37	25'	120	.500	240	21.0	0.58	36%	1.611
38	39'	140	.500	280	28.0	2.54	42%	6.048
74	15'	250	.330	757	6.0	2.87	7%	41.000
164	40'	110	.500	220	36.0	4.07	54%	7.537
165	40'	350	.500	700	11.4	1.88	17%	11.059
418	35'	150	.500	300	23.0	1.52	37%	4.108

Figure 21. Map showing Patuxent specific capacities superimposed upon progadational deltaic lobes.



SOURCE: DANIELS, ONUSCNAK (1974)

foot per foot of drawdown). The formula is as follows:

$$K = \frac{24}{T} \cdot \frac{Q}{Sh\pi D}$$

Where: K = hydraulic conductivity in Meinzers

T = total hours pumped

Q = total gallons discharged

S = drawdown in feet

h = thickness in feet of permeable section of the aquifer

π = 3.14159

D = diameter of the hole in feet

To modify this formula for gallons per minute:

$$K = \frac{Q \cdot 1440}{Sh\pi D}$$

As an example of this measurement, the hydraulic conductivity (average permeability) can be calculated for SWCB well #142-1. The discharge or yield (Q) is 17 GPM. The drawdown (S) is 79 feet with the screened section of the aquifer (h) equaling 20 feet. The diameter of the hole (D) is 0.5 feet. Therefore:

$$K = \frac{(17\ \text{GPM})\ (1440\ \text{minutes/day})}{(79')\ (20')\ (3.14159)\ (0.5')}$$

$$K = \frac{24480}{2481.856} = 9.863 \text{ gallons per minute per square foot per foot of drawdown}$$

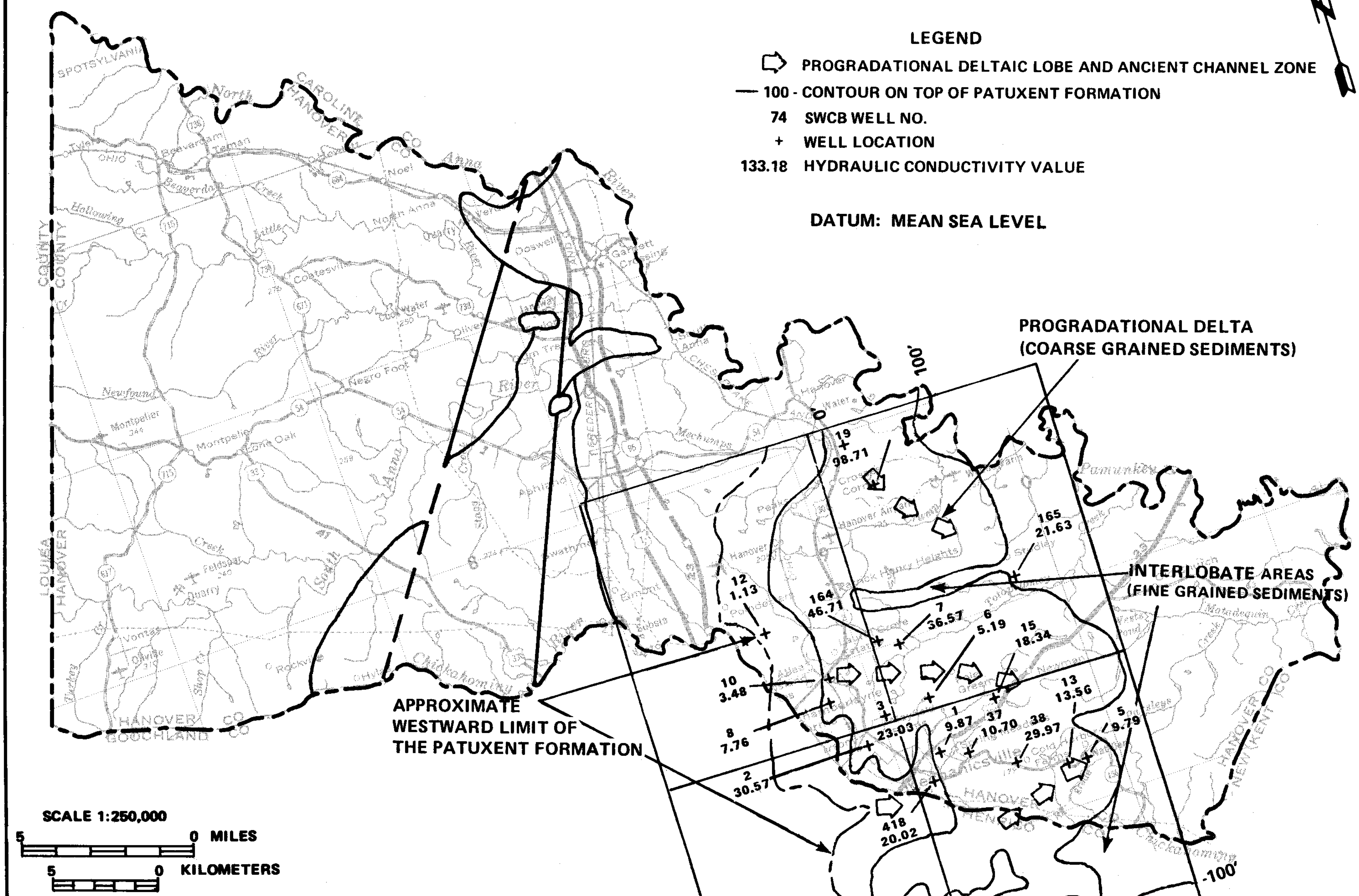
To understand the potential yield of an aquifer, the hydraulic conductivity (permeability) is the best, but the most complex method.

Table 8 lists the hydraulic conductivity values in the Patuxent Formation of Hanover County for wells with know specific capacities. Figures 22a and 22b locate these values on the Hanover County map.

Table 8. Hydraulic Conductivity - Patuxent Aquifer

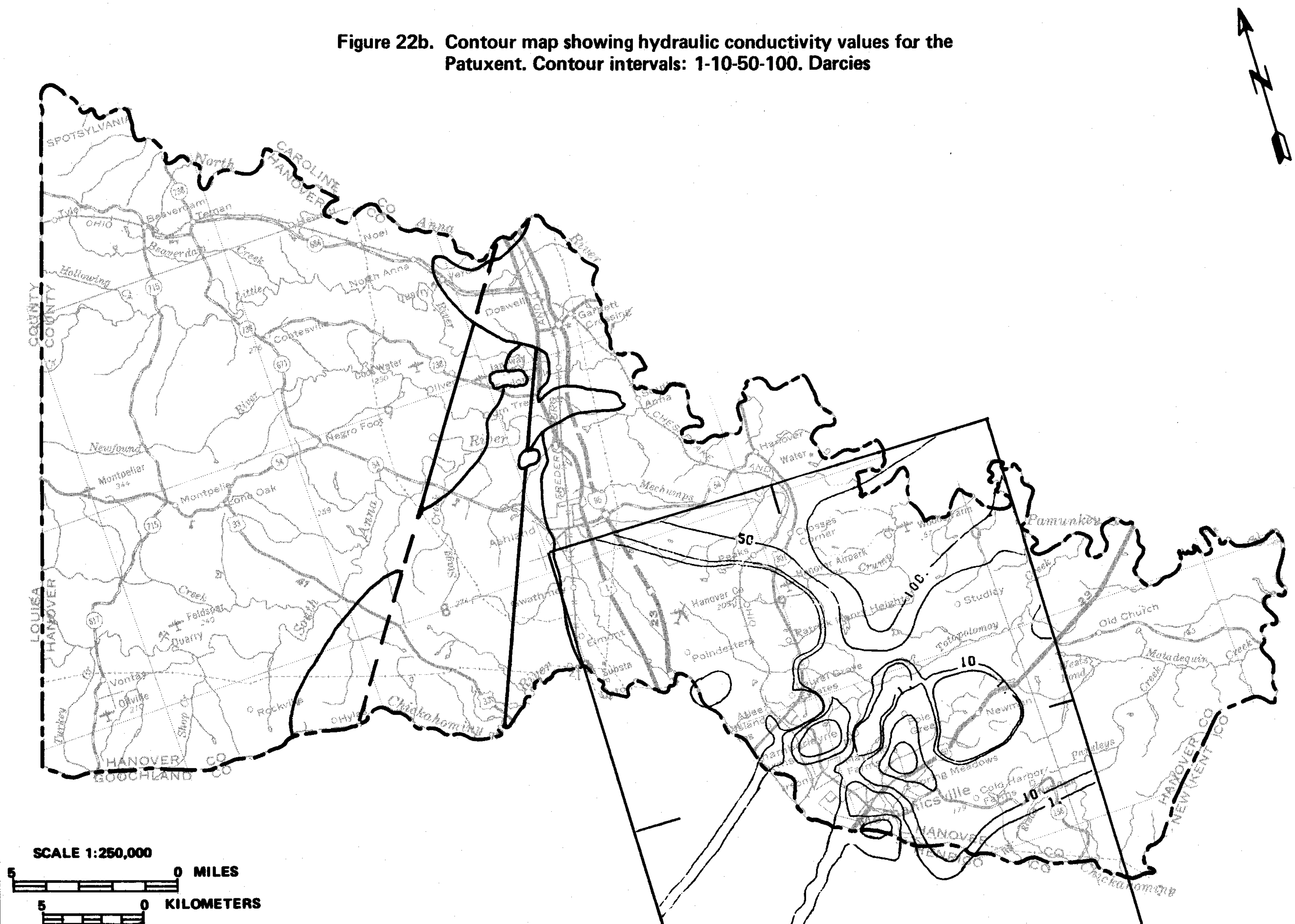
SWCB Well #	Hydraulic Conductivity (GPM per square foot per foot of drawdown)
1	9.87
2	30.87
3	23.03
5	9.79

Figure 22a. Map showing Patuxent hydraulic conductivities superimposed on progradational deltaic lobes. (Hydraulic conductivity values in darcies)



SOURCE: DANIELS, ONUSCHAK (1974)

Figure 22b. Contour map showing hydraulic conductivity values for the Patuxent. Contour intervals: 1-10-50-100. Darcies



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

6	5.19
7	36.57
8	7.76
10	3.48
12	1.13
13	13.56
15	18.34
19	98.71
37	10.70
38	29.97
74	133.18
164	46.71
165	21.63
418	20.02

Hydraulic conductivity is an approximate value for the true permeability of the aquifer. High values indicate a more permeable zone with greater groundwater potential (Table 9). The zones of high, hydraulic conductivity values generally correlate with the Patuxent progradational deltaic lobes and give a better definition of the aquifer potential than the specific capacity values.

The percentage of sand present in a well is also used to estimate potential groundwater production. Sand percentages of several Patuxent wells have been calculated from the geophysical logs. The percentage of the well depth determined to consist of sand is a good reference for comparing groundwater yield potentials. Figure 23 shows wells whose sand percentages have been determined. Contour lines were plotted by computer to correlate the data.

Conclusions. It is believed that the greatest, potential, groundwater source areas of the Patuxent Formation are in the progradational deltaic lobes. A composite of the sand percentage, specific capacity, and hydraulic conductivity values indicates that the coarse-grained, delta channel fillings provide the best groundwater supplies. The interlobate areas are low-potential, groundwater-yield areas. Braiding of the distributaries and sinuous migration of the channels through time have made the Patuxent in Hanover County a very complex aquifer. More detailed delineation of the subsurface is a necessary prerequisite for

TABLE 9

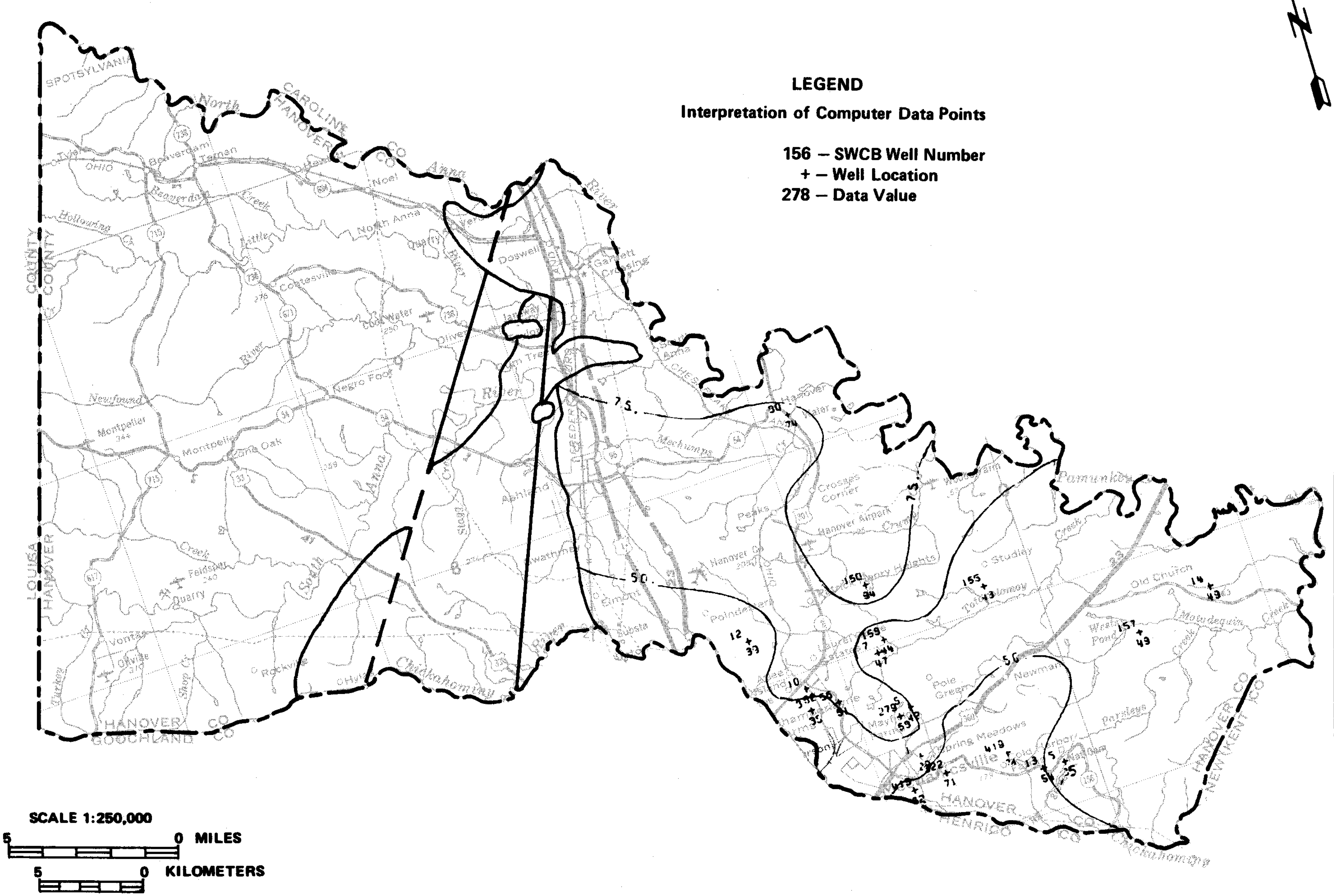
COMMON PERMEABILITIES AND

HYDRAULIC CONDUCTIVITIES (at 60°F)

Groundwater Production	Permeability (Darcies)	Hydraulic Conductivity (Meinzers)	Rock or Soil Material
Very Good Flow	over 1000	over 18,200	unconsolidated, clean, well-sorted sand and gravel, open coquina, open fractures and fault zones, open limestone caverns and solution vugs, open breccia
Good Flow	5.5-1000	100-18,200	packed, clean gravel, dune sand, fine, unconsolidated, clean sand, packed, clean coarse sand
Average Flow	0.275-5.5	5-100	moderately-indurated-and-cemented, clean, well-sorted sandstone, silt, loess
Low Flow	0.11-0.275	2-5	very-indurated-and-cemented, clean sandstone and siltstone, poorly-sorted sand and sandstone
Very Low Flow	0.055-0.11	1-2	sucrosic dolomite, quartzite, clayey siltstone and sandstone
No Flow	less than 0.055	less than 1	clay, shale, mudstone, unweathered, crystalline limestone and dense dolomite, unweathered igneous and metamorphic rocks, graywack, salt, iron ore, massive chert

SOURCE: SWCB-PRO, BWCM

Figure 23. Sand percentages and contours of several Patuxent Formation wells.



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

better county groundwater understanding.

Cretaceous Period (Patuxent) - Groundwater Quality. The Patuxent Formation (Kptx) contains soft-to very-hard water. Total hardness values range from 3 to 4 ppm at well #165 and well #207 to 234 ppm at well #10. This broad range is presumed to be caused by variations in calcium and magnesium carbonate concentration zones in the overlying, fossiliferous, transgressive formations through which the vertically-percolating groundwater must pass.

Specific conductance values range from 93 micro-mhos/cm at well #38 to 805 micro-mhos/cm at well #8, indicating highly-variable ion concentrations throughout the Patuxent. Total dissolved solids also show a broad range with values ranging from 136 ppm at well #171 to 763 ppm at well #10. The dissolved ion concentrations of the Patuxent are consistently higher than those of the "basement complex" below, and the Piedmont rocks to the west.

Groundwater is slightly basic in the Patuxent. Hydrogen ion concentrations values (pH) are commonly in the 7.0 to 9.0 range. Iron is not usually a problem because most Patuxent well water values are less than 0.1 ppm. Chloride concentrations tend to increase eastward with the highest value at well #10 (544 ppm). Fluctuations of chloride values have been noted in the Patuxent due to drought conditions and the dissolution of subsurface, Patuxent saline bay deposits. Fluorides, like chlorides, generally increase eastward with highest values at well #10 (8.5 ppm); however, localized, high fluoride values do exist.

Very little surface nitrate contamination reaches the confined Patuxent aquifer, but nitrate values do increase in the surface outcrop areas of the formation (well #315-13.7 ppm) (Figure 7a). These values possibly are caused by manure, fertilizer, and septic field contamination.

Late Cretaceous and Tertiary Periods (75 to 36 million years old). The Late Cretaceous and Tertiary sediments (TK) are greenish-gray, glauconitic, silty sands that were deposited during several minor, marine transgressions (Figure 7a and 7b). In the western Coastal Plain near the Fall Zone, the subsurface Cretaceous and Tertiary units usually are discussed collectively, but in the east they are designated as the Mattaponi Formation (Tmat), its Marlboro Clay member (Tma), and the Nanjemoy (Tn) Formations.

The Mattaponi thins out on top of the Patuxent in the western part of the Coastal Plain, with the greatest thicknesses (160 feet; 48.8 meters) noted in the northeastern portion of the county (Figure 24). The Marlboro Clay member is only a few feet thick and separates the Mattaponi below from the Nanjemoy above. The Nanjemoy lies unconformably upon the Mattaponi and has thicknesses of over 120 feet (36.6 meters) in the eastern margins of the County (Teifke, 1973, Plate 9). Both formations are fairly permeable and porous in their basal portions, but grade into clays and silts upward.

The lower units of the Mattaponi are very similar in geohydrologic characteristics to the Patuxent deposits beneath them. The upper units of the Mattaponi are designated as confining units due to their less-permeable nature. These upper units act as an aquitard and hinder recharge of the principal artesian aquifer (Patuxent).

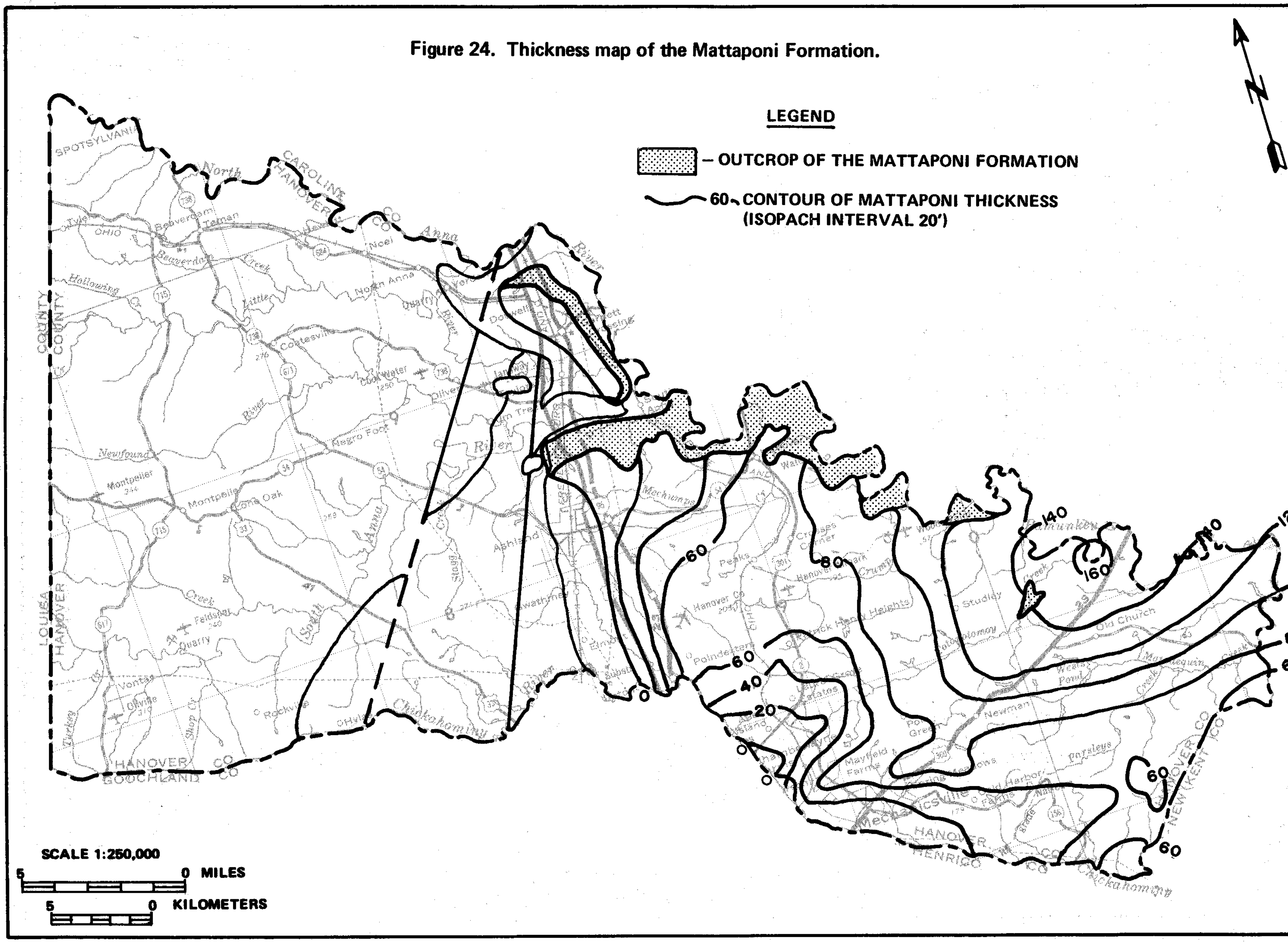
The Marlboro Clay member is a key formation boundary noted throughout much of the Coastal Plain and acts as a part of the confining layer (aquitard) between the principal and upper artesian aquifers.

The lower units of the Nanjemoy formation are very permeable and consistantly contain moderate supplies of groundwater. (The name Aquia has been used previously for surface exposures of the Nanjemoy.) This zone is referred to as the upper artesian aquifer in the easternmost part of the County where thicknesses and confinement allow artesian conditions to prevail. The uppermost Nanjemoy acts as a confining unit and is composed of finer grained silts and clay (Figure 25).

Late Cretaceous and Tertiary - Groundwater Quality. The lower Mattaponi (Tmat) is the upper portion of the principal artesian aquifer, with water quality very similar to the Patuxent. The less-permeable, upper Mattaponi acts as a confining layer with little or no groundwater yield. This confining layer hinders the vertically-percolating groundwater that recharges the Patuxent, and thus increases the groundwater renovation time.

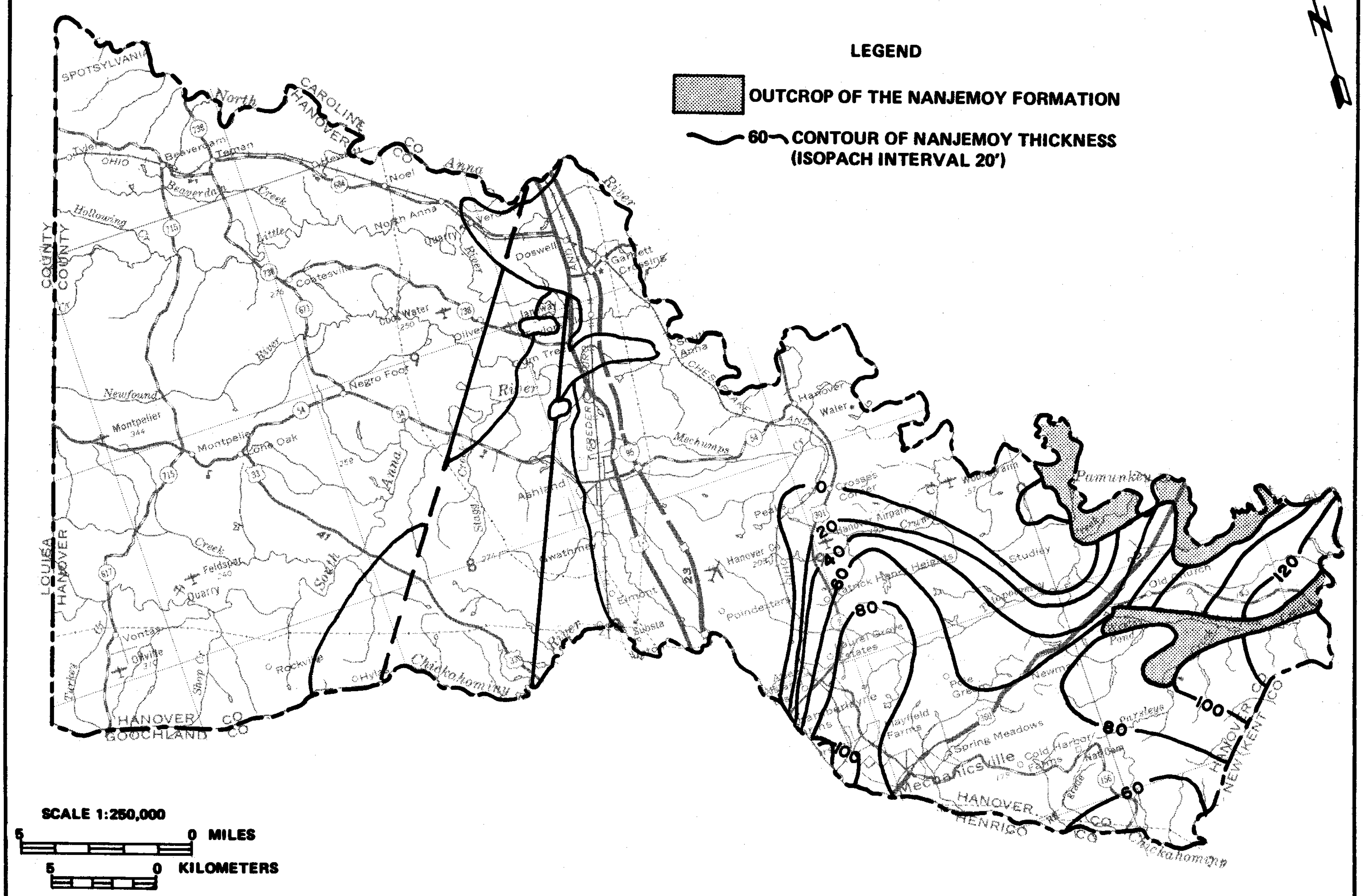
The lower Nanjemoy (Tn) is the upper artesian system. Its chloride content increases eastward, but, overall, remains quite low. The

Figure 24. Thickness map of the Mattaponi Formation.



SOURCE: TIEFKE, 1973.

Figure 25. Thickness map of the Nanjemoy Formation.



SOURCE: TIEFKE, 1973.

groundwater is generally soft. Values for both the dissolved solids and specific conductivity are low. Iron values are very low. The pH ranges from 5 to 7 or slightly acidic. Nitrates can be very low (0.0 ppm at well #383) or high (57.6 ppm at well #382). High nitrate values are probably the result of contamination from animal wastes and fertilizers. The upper Nanjemoy is a confining unit (aquitard) that extends into the Miocene clayey silt above.

Miocene Epoch (Clayey Silt) (25 to 13 million years old). The Miocene clayey silt (Tcs) unconformably overlies the Nanjemoy, Mattaponi, Patuxent, and Petersburg Granite formations. These marine-transgressive beds of clayey silt act as an aquitard or confining unit over the upper artesian aquifer system (upper Nanjemoy). Thicknesses of the unit vary from 0 to 40 feet (0 to 12 meters) in eastern Hanover County. Permeabilities are very low in the clayey silt, but porosity values are high due to the vast amount of intergranular pore space in the clays and silts. Therefore, the beds of clayey silt vertically recharge the upper artesian system at a very slow rate. Owing to their porosity, thickness and extent, they have a tremendous groundwater storage capacity.

Only very low yields (1 to 3 gpm; 3.8 to 11.4 liters per minute) of domestic groundwater can be obtained from the clayey silt especially in the upper portions of the unit. Wells that tap the clayey silt are listed in Table 10.

Miocene Epoch (Clayey Silt) - Groundwater Quality. Permeabilities are very low in the Miocene clayey silt (Tcs). The slow rate of vertical recharge through this confining unit causes a high degree of filtration and chemical action. Water quality is increased notably upon percolation through this formation. Samples from wells in the clayey silt generally show high quality water which is low in most impurities with the possible exception of nitrates.

The upper clayey silt units are part of the water table system and produce high-quality groundwater, but do have an increased risk of surface contamination and drought-related shortages (Figure 17).

TABLE 10

Water Wells Which Tap the Miocene Clayey-Silt And Tertiary-Quaternary Sands and Gravels

SWCB Well Number	Total Depth	SWCB Well Number	Total Depth
103	30'	320	35'
194	50'	321	23'
195	50'	341	49'
238	60'	344	38'
242	35'	371	60'
244	39'	373	50'
255	40'	375	60'
263	40'	376	30'
264	40'	378	45'
265	40'	380	30'
266	50'	384	40'
300	50'		
302	28'		
303	20'		
305	30'		
306	42'		
316	70'		
318	40'		
319	50'		

Late Tertiary and Quarternary (13 million years old to Recent). The Late Tertiary and Quaternary deposits consist of sands and gravels (sg) (Regressive Sediments) (Figure 7a). These regressive sands and gravels have been called the Brandywine Formation (Brown, 1939), Lafayette Formation (Darton, 1911), and Columbia Group (Cederstrom, 1957; Teifke, 1973). The thickness of these post-Miocene sands and gravels increases eastward with more than 80 feet (24 meters) noted in eastern Hanover County (Daniels, p. 29, 1974).

The Late Tertiary and Quarternary sands and gravels (sg) are clean, oxidized, unconsolidated, regressive sediments overlying the Miocene clayey silt (Figures 7a and 17). They contain the upper water table system and are the source for most of the County's domestic and light farming water supplies. The deposits are usually alluvium and channel fillings along with terrace deposits. Many of the wells are dug or shallow bored wells with 36" diameters (0.4 meters) and yields ranging from 5 to 15 GPM (18.4 to 56.8 liters per minute).

Some springs are utilized as sources of groundwater and have yields as high as 30 GPM (113.6 liters per minute). They originate from the base of terrace deposits on the banks of steep ravines (Cederstrom, 1957, p. 82). Due to natural inaccessability and risks of surface contamination, most springs are not used. Drought conditions can affect the shallow springs and wells located in the sands and gravels. If a large yield or continuous supply is needed, as for an industry or municipality, it is recommended that a deeper well be drilled into a more extensive aquifer.

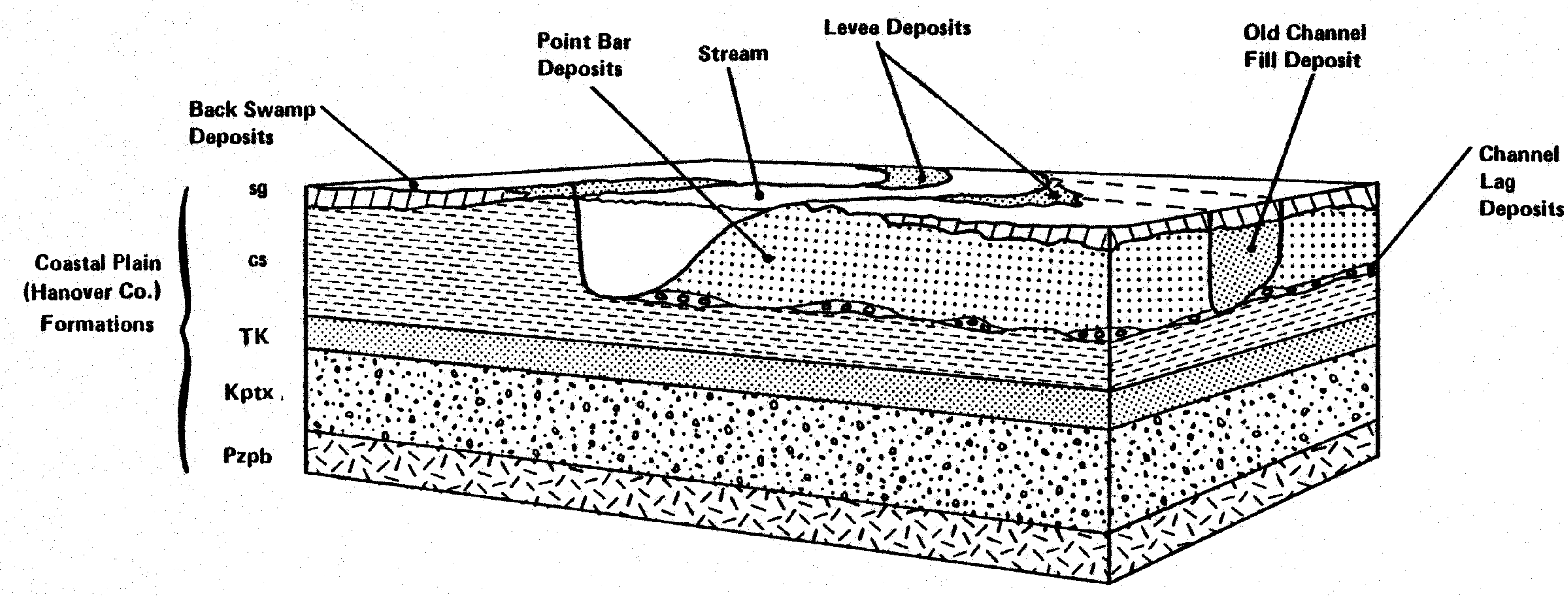
Late Tertiary and Quaternary - Groundwater Quality. Most domestic supplies tap the sand and gravel which make up this shallow water table system. Although this system contains high quality water (low in mineral content), it occasionally shows some evidence of possible organic pollution. The low mineral content is attributable to the short time the water is in intimate association with the clean sands and gravels.

Quaternary - Alluvium (Recent Time). Varying amounts of alluvial deposits (al) are noted throughout the present drainageways in Hanover

County (Figure 7a). The common alluvial structures include natural levees, alluvial fill, abandoned channels, and point-bar deposits, each of which contains varying amounts of different-sized sediments ranging from clays to gravels.

Quaternary - Alluvium - Groundwater Quality. Alluvial (al) deposits are usually of such minor extent and thickness (1 to 15 feet; 0.3 to 4.6 meters) that they rarely are capable of containing significant groundwater supplies. The greatest thicknesses are usually found next to an active drainageway with contamination a constant threat. Health officials usually advise against locating a well in such an easily-contaminatable aquifer (Figure 26).

Figure 26. Schematic cross-section showing alluvial deposits of a typical Coastal Plain stream.



SOURCE: STATE WATER CONTROL BOARD – PRO

CHAPTER V

GROUNDWATER QUALITY

General

Groundwater quality information is collected throughout the Commonwealth on a continuous basis by the staff of the State Water Control Board. The quality information obtained enables the Board to keep close surveillance on groundwater quality fluctuations and areas of potential groundwater pollution. Background sampling is performed in order that groundwater degradation can be ascertained. All of this information is correlated with other well data to enable more efficient groundwater resource management.

This chapter will discuss the methods of quality data collection and storage, the chemical parameters tested for, and how the major quality parameters relate to the geohydrology of an area. Computer-drawn contour maps of each major parameter for the entire County and for the major aquifers are provided.

Hanover County groundwater quality information was obtained from newly completed, public-use wells, State Health Department records, from past groundwater sampling by the State Water Control Board, and from ongoing groundwater sampling procedures carried out by the Piedmont Regional Office. Many high-use wells, notably public supply and industrial wells, are tested on a periodic basis. A better understanding of quality fluctuations through time and usage is, therefore, acquired through the sampling program.

Groundwater quality data for Hanover County is stored on computer by the State Water Control Board and is updated on a quarterly basis. Sixty-three possible water-quality parameters are entered, with fifteen major parameters displayed on the quarterly print-out.

All groundwater quality information is determined by standard, approved, chemical-analysis techniques performed by the Commonwealth of Virginia Consolidated Laboratory in the Division of Environmental Sciences. Parameters tested for in each State Water Control Board groundwater sample include: pH (laboratory), alkalinity/acidity (mg/l as $CaCO_3$), total solids (total, volatile, and fixed), suspended solids (total, volatile, and fixed), total organic carbon, fluoride, chloride, hardness-EDTA (mg/l as $CaCO_3$), nitrogen (total Kjeldahl), phosphorus, ammonia (mg/l as N), nitrite and nitrate (mg/l as N), nitrite (mg/l as N), sulphate, cadmium, iron, magnesium, manganese, sodium, potassium, total coliform/100 ml-MPN, fecal coliform 100 ml-MPN, and conductivity (micro-mhos/cm). A table of major parameters and their recommended maximum concentrations is provided (Table 11).

Almost all of the dissolved minerals found in groundwater are added as the water percolates through the subsurface. A chemical equilibrium is reached for each mineral as its ion concentration approaches saturation levels. Temperature, pressure, and groundwater volume directly affect this process. Many variables such as vegetation, amount of precipitation, pH, geology, and formation composition also affect groundwater quality.

The usefulness of groundwater is related directly to the kinds and amounts of dissolved minerals, as well as the chemical characteristics of the water. Groundwater usually contains only minor amounts of dissolved solids and virtually no bacteria, making it far superior to surface water in these respects.

The ion concentrations of the dissolved minerals are usually of prime concern in a chemical analysis. The major properties of groundwater that best reflect its overall quality are: hardness, specific electrical conductance, hydrogen ion concentration (pH), total dissolved solids, iron (Fe^{++}), chloride (Cl^-), fluoride (F^-), and nitrate (NO_3^-). These are usually reported as milligrams per liter (mg/l) or in parts per million(1ppm-one part by weight of the dissolved substance contained in one million parts, by weight, of the solution).

<u>Major Groundwater Quality Parameters</u>

<u>Hardness</u>. This parameter refers to the soap-wasting properties of the water. Equal quantities of both soap and calcium-magnesium ions

Table 11. Groundwater Quality Parameters

Substance	Maximum Recommended Concentration (mg/l)*	Remarks
Bicarbonate	150	Seldom considered detrimental; lower amount recommended for washing
Calcium	200	Seldom a health concern; may be a disadvantage in washing, laundry, bathing; encrustations on utensils
Chloride	**250 (Esthetics)	Taste is a major criterion; generally not harmful unless in very high concentrations, but may be injurious to sufferers of heart and kidney diseases; sea water is 19,000 mg/l
Fluoride	**1.4 (Health)	Presence of about 1.0 mg/l may be more beneficial than detrimental; above 0.8 mg/l may cause mottling of teeth; extreme doses (4 drams) may cause death
Hardness (as $CaCO_3$)	0-60 Soft 61-120 Mod. Hard 121-180 Hard above 180 Very Hard	Hard waters have had no demonstrable harmful effects upon the health of consumers; major detrimental effect is economic--values above 100 mg/l become increasingly inconvenient; wastes soap and causes utensil encrustation
Iron	**0.3 (Esthetics)	Essential to nutrition and not detrimental to health unless in concentrations of several milligrams; main problems are bad taste, staining, and discoloration of laundry and procelain fixtures
Magnesium	150	Not a health hazard because taste becomes extremely unpleasant before toxic concentrations reached; may have laxative effect on new users
Manganese	**0.5 (Esthetics)	Essential to nutrition but may be toxic in high concentrations; taste becomes problem before toxic concentrations reached; undesirable because it causes bad taste, deposits on cooked food, stains and discolors laundry and plumbing fixtures
Nitrate	**10 as N, 45 as NO_3 (Appendix B listed as NO_3, Health Dept. as N) (Health)	May be extremely poisonous in high concentrations; may cause disease in infants ("blue baby"); irritates bladder and gastrointestinal tract, may cause diarrhea
pH	5.5-8.0	Indicates whether solution will act as an acid or base; water acquires "sour" taste below 4; high values favor corrosion control; efficiency of chlorination severely reduced when pH above 7
Potassium	1,000-3,000	May act as a laxative in excessive quantities
Sodium	100	May be harmful to sufferers of cardiac, circulatory, or kidney disease; concentrations as low as 200 mg/l may be injurious
Solids (Total Dissolved)	500	Not a health hazard above 500 mg/l but may impart disagreeable taste, corrode pipes; general indicator of how highly water is mineralized
Specific Conductivity	1000	As indicator of the amount of dissolved solids in water; high concentrations can cause corrosion of iron and steel
Sulfate	**250 (Esthetics)	Above 250 mg/l may act as a laxative on new users; may impart foul taste and odor

* Recommended concentrations based on current literature

** Actual limits established by the Virginia Department of Health; parentheses () indicate basis for limit

Source: McKee and Wolf (1963); Virginia Department of Health present in the water must combine before soap suds can begin forming. Dissolved carbon dioxide in water enables the ionic dissociation of limestone and dolomites (calcium and magnesium carbonates). These supply the calcium and magnesium ions which cause most hardness. The remaining carbonate ions combine with the dissolved carbon dioxide to form bicarbonates. Calcium carbonate incrustation (scale) forms when the carbon dioxide is driven off and the calcium and magnesium ions recombine with the carbonate ions, the amount of combining aluminum, zinc, iron, manganese ions, and strontium are included to determine total hardness.

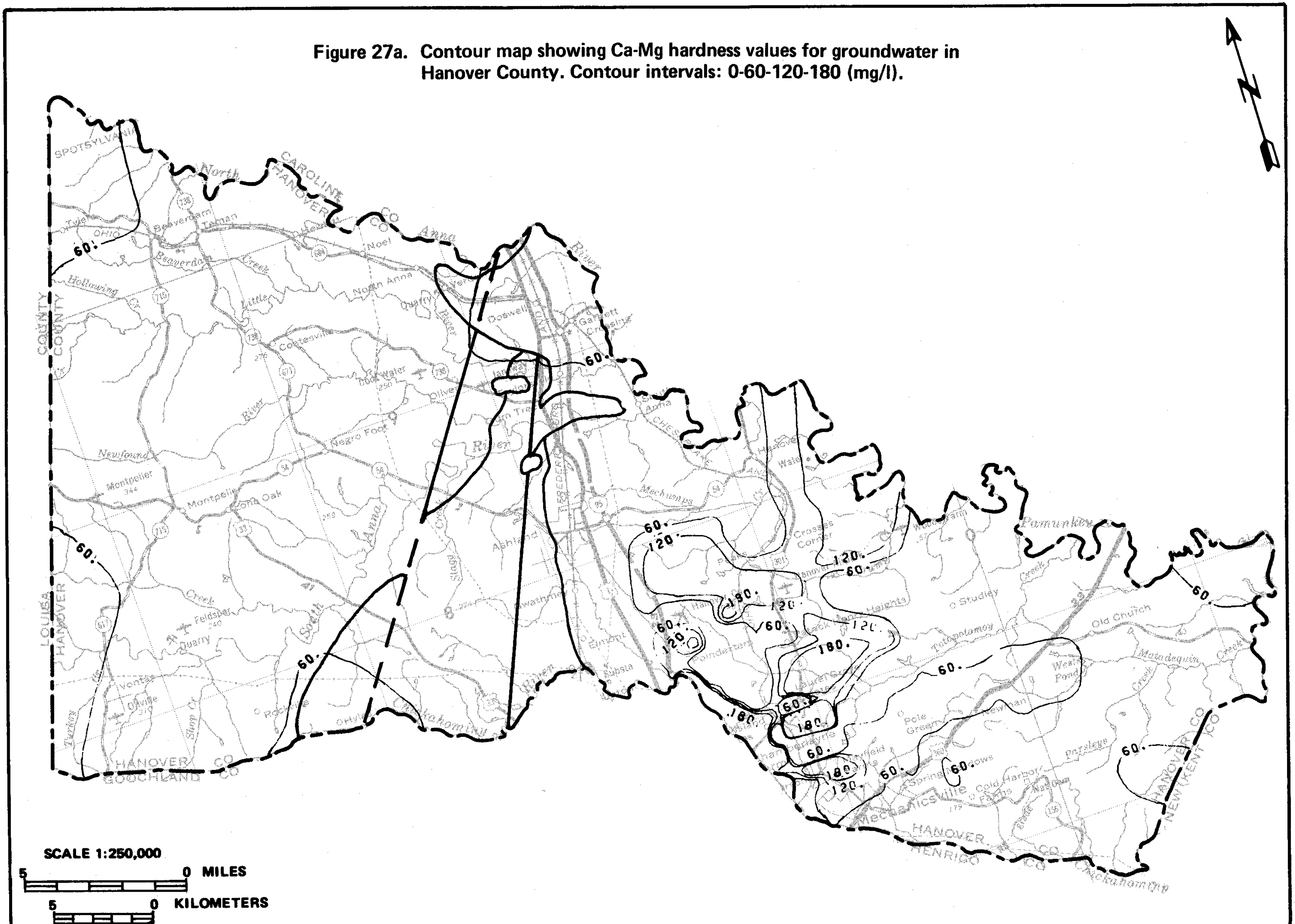
Hardness values greater than 150 ppm are very noticeable. Values greater than 200 ppm often make it necessary to soften the water for household use. It becomes very uneconomical to soften groundwater when the hardness values are extremely high.

Hardness values for groundwater in Hanover County range from very hard to soft depending on aquifer and location. The Piedmont rocks generally yield soft water. The overall tendency in the Coastal Plain is for the groundwater to increase in hardness eastward, but beyond a certain point the water becomes softer. In these soft areas the calcium has been replaced by sodium (base exchange). This change can be seen in Figures 27a and 27b.

Groundwater from most of the Piedmont rocks is fairly soft, with many wells yielding water with calcium and magnesium ion concentrations far less than 60 ppm (Figures 27a and 27c). Calcium and magnesium hardness east of the Fall Zone increases in the basement complex rocks as seen in Figure 27b.

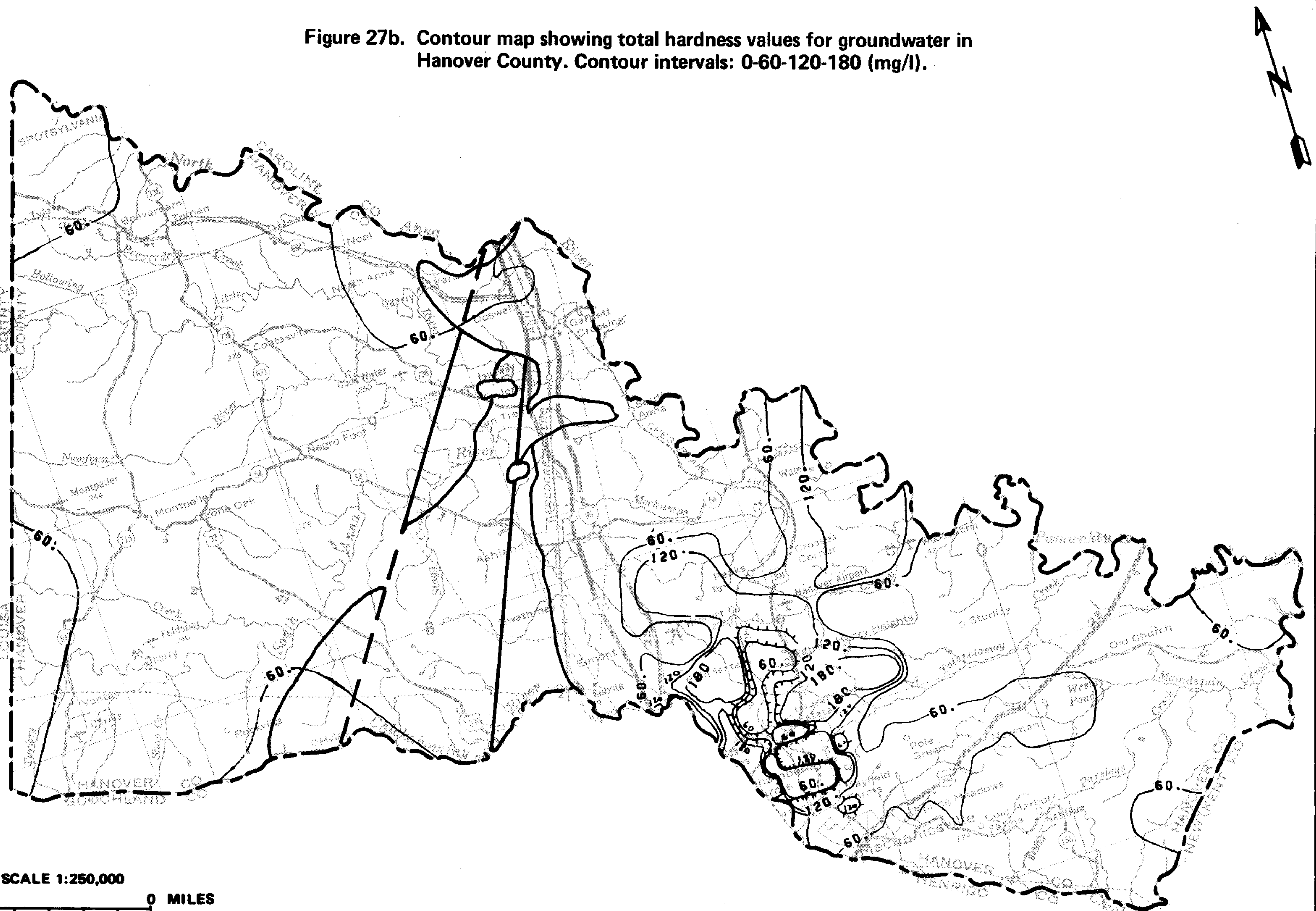
Groundwater from the Coastal Plain Cretaceous aquifer (Patuxent) in the Mechanicsville and Hanover Courthouse areas is fairly hard. Here ancient evaporative bays and prograding deltas, associated with sea regression, in addition to the overlying Miocene fossiliferous (calcium carbonate and aragonite) formations through which the groundwater percolates, have helped to increase the calcium and magnesium ion concentrations in the groundwater (Figure 27d).

Figure 27a. Contour map showing Ca-Mg hardness values for groundwater in Hanover County. Contour intervals: 0-60-120-180 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 27b. Contour map showing total hardness values for groundwater in Hanover County. Contour intervals: 0-60-120-180 (mg/l).



SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

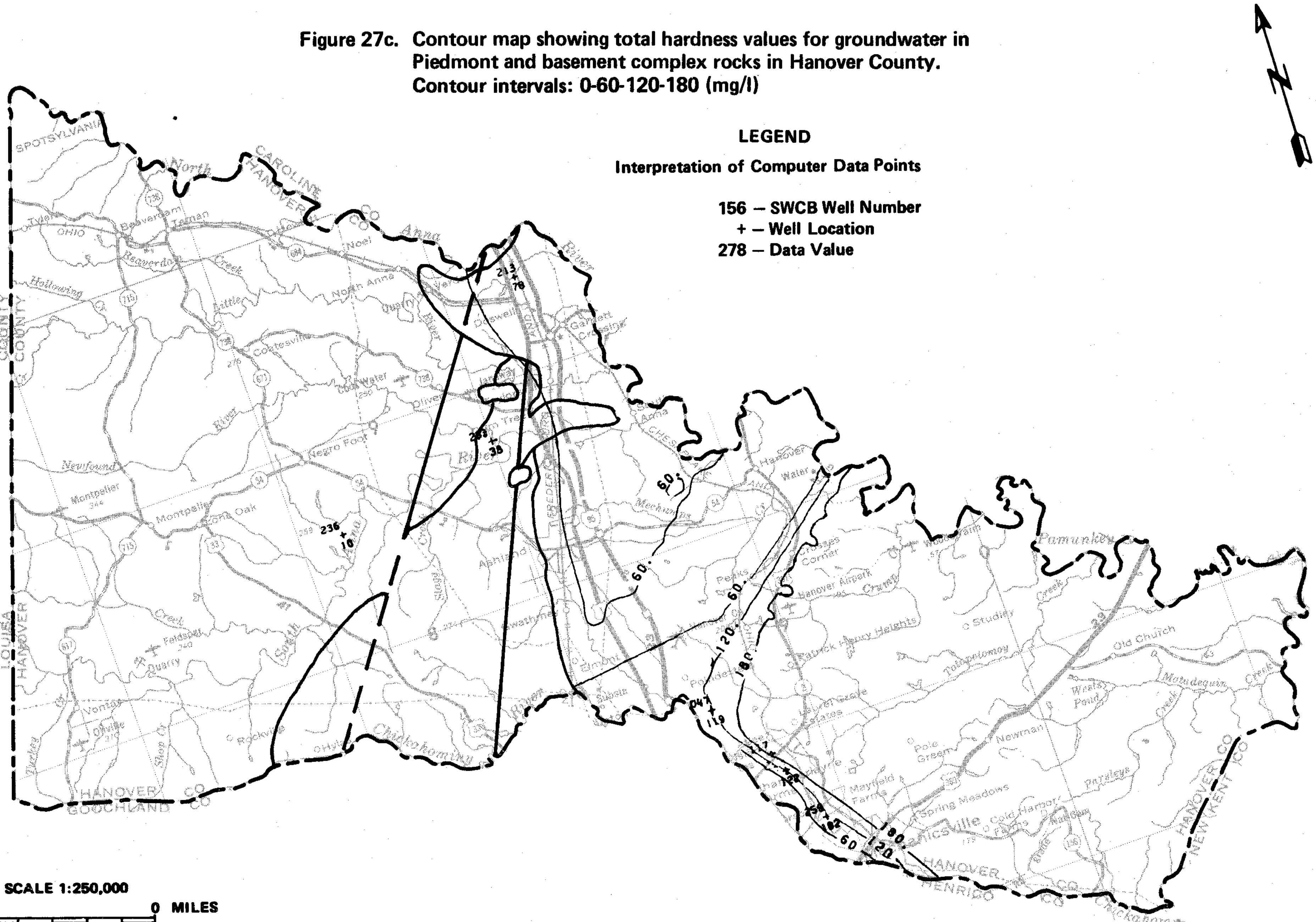
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 27c. Contour map showing total hardness values for groundwater in Piedmont and basement complex rocks in Hanover County. Contour intervals: 0-60-120-180 (mg/l)

LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value



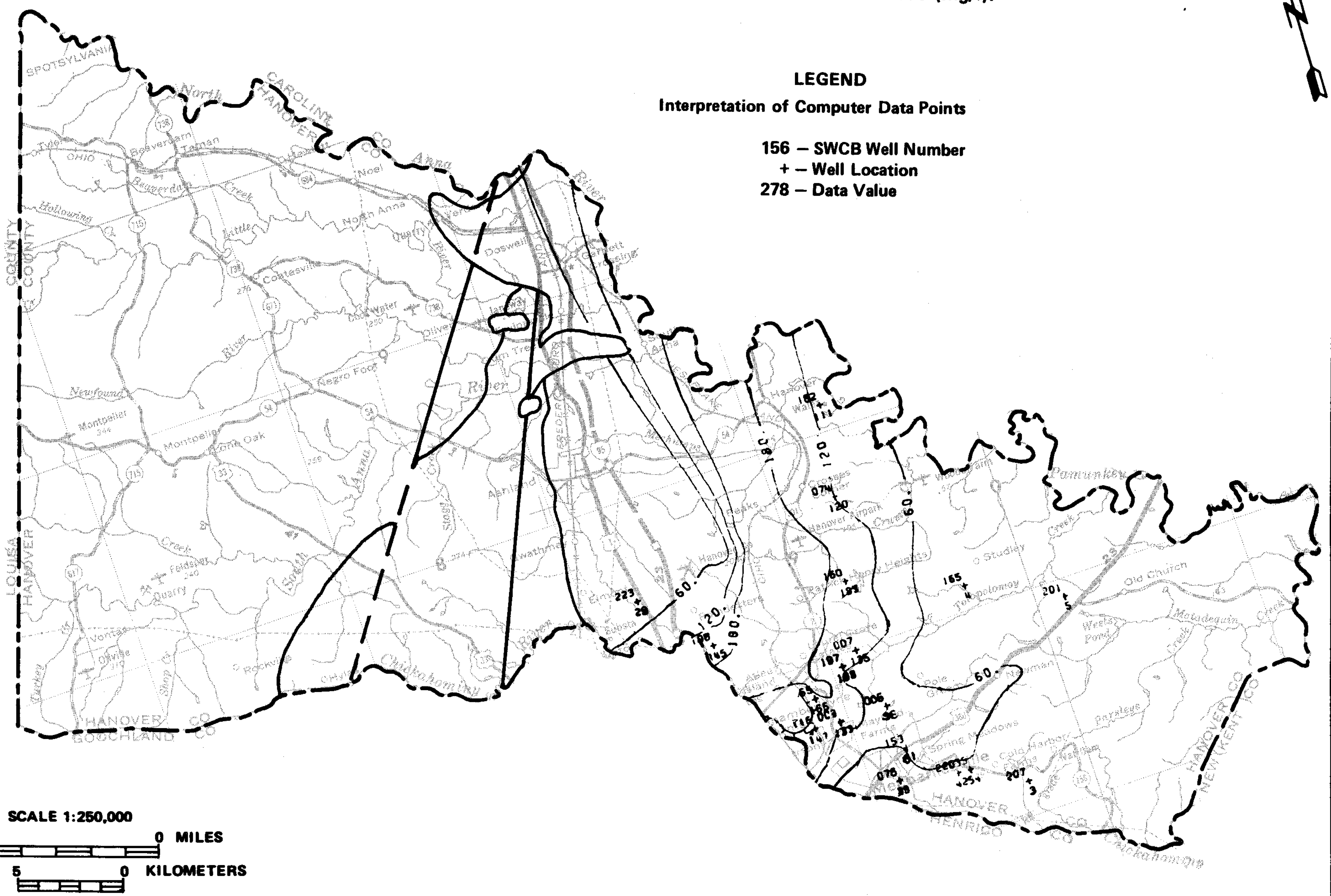
SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 27d. Contour map showing total hardness values for groundwater in the Patuxent Formation. Contour intervals: 0-60-120-180 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Groundwater from shallow wells that draw from the Tertiary-Quarternary sands and gravels and reach down to the Miocene clayey-silt has very low hardness values. Values below 40 ppm are not uncommon in these transgressive-regressive deposits, with a noteworthy decrease in hardness seen in the more shallow wells (Figure 27e).

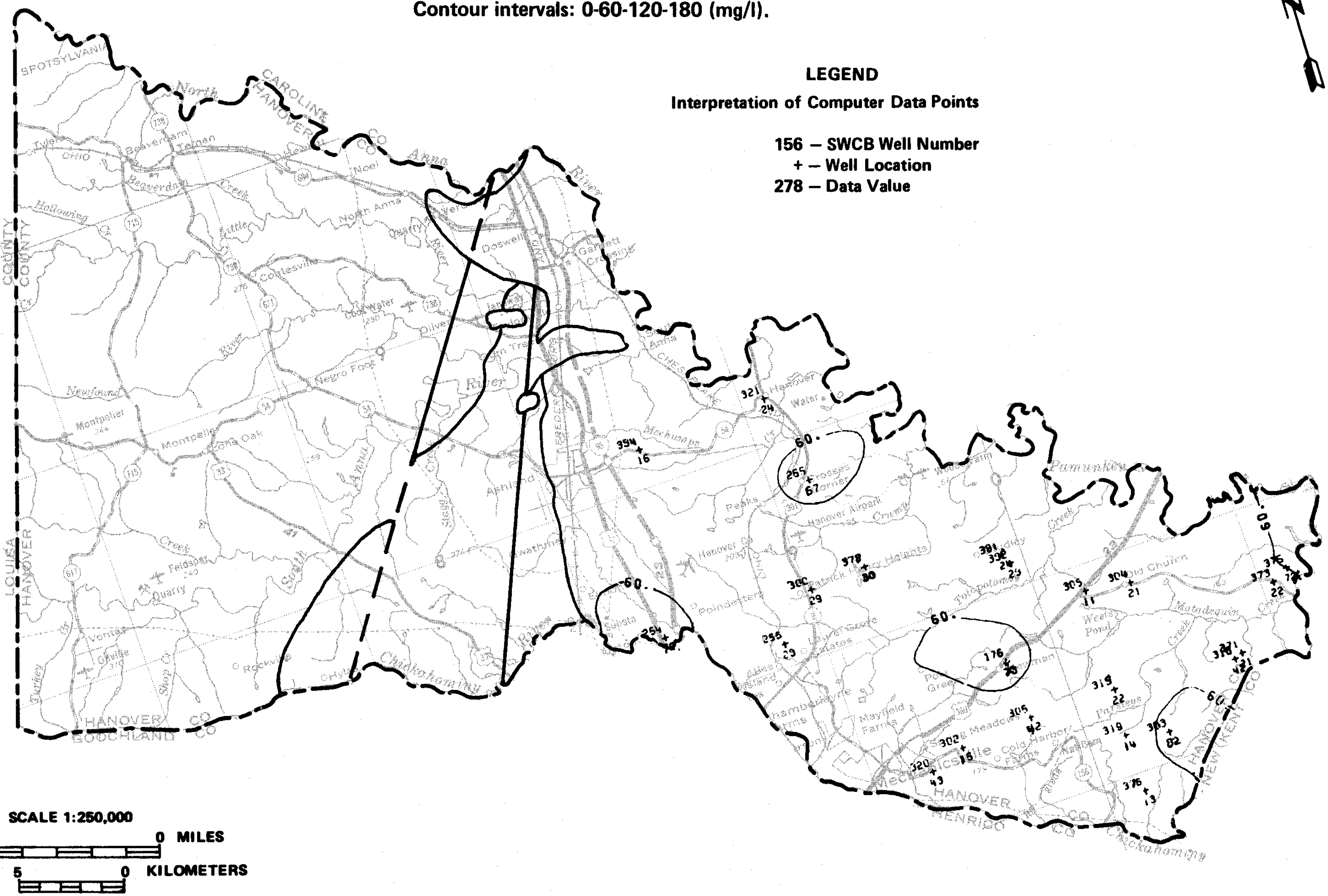
Wells with the highest hardness values include: #117, 217 ppm at Craney Island Estates and #119, 332 ppm at Blue Star Estates.

Specific Conductance. Specific "electric" conductance is the ability of groundwater to conduct electric current and is measured through one cubic centimeter of the water sample. Chemically-pure water is a good insultator, but any increase in the amount of dissolved minerals will greatly increase the specific conductance of the water sample. High values for specific conductance can indicate that corrosion of iron and steel will occur. Two areas of highest specific conductance are southeast of Poindexters and south of Atlee (Figure 28a) (well #8, 805 micro-mhos/cm and well #198, 600 micro-mhos/cm). Computer-drawn contours for specific conductance values from the Piedmont and basement complex rocks, Patuxent, and Miocene clayey-silt and Tertiary-Quaternary sand and gravel aquifers are included on Figures 28b-d.

Hydrogen Ion Concentration (pH). An increase in the hydrogen ion concentration (H^+) causes the water to act like an acid and has a characteristically low pH value. Values for pH range from 0 to 14, with 0 being most acidic, 14 most basic (alkaline), and 7 representing a neutral solution. Each unit of pH indicates a 10-fold change in the hydrogen ion concentration.

Most groundwater has its pH controlled by the carbon dioxide-bicarbonate relationship. An increase in dissolved carbon dioxide makes the water more acidic due to the production of carbonic acid. Any dissolved bicarbonate will make the groundwater more basic (alkaline). The equilibrium between these acidic and basic components determine most groundwater pH. Since carbon dioxide can escape rapidly from a water sample, thus reducing the acid content, field pH tests are more accurate than laboratory tests. In the Groundwater Quality Listing (see Appendix 3), the high pH values, found in State Water Control Board wells with low listing numbers, relate to the loss of acid forming CO_2 from the samples

Figure 27e. Contour map showing total hardness values for groundwater in the Miocene clayey-silt and Tertiary-Quaternary sand and gravels. Contour intervals: 0-60-120-180 (mg/l).



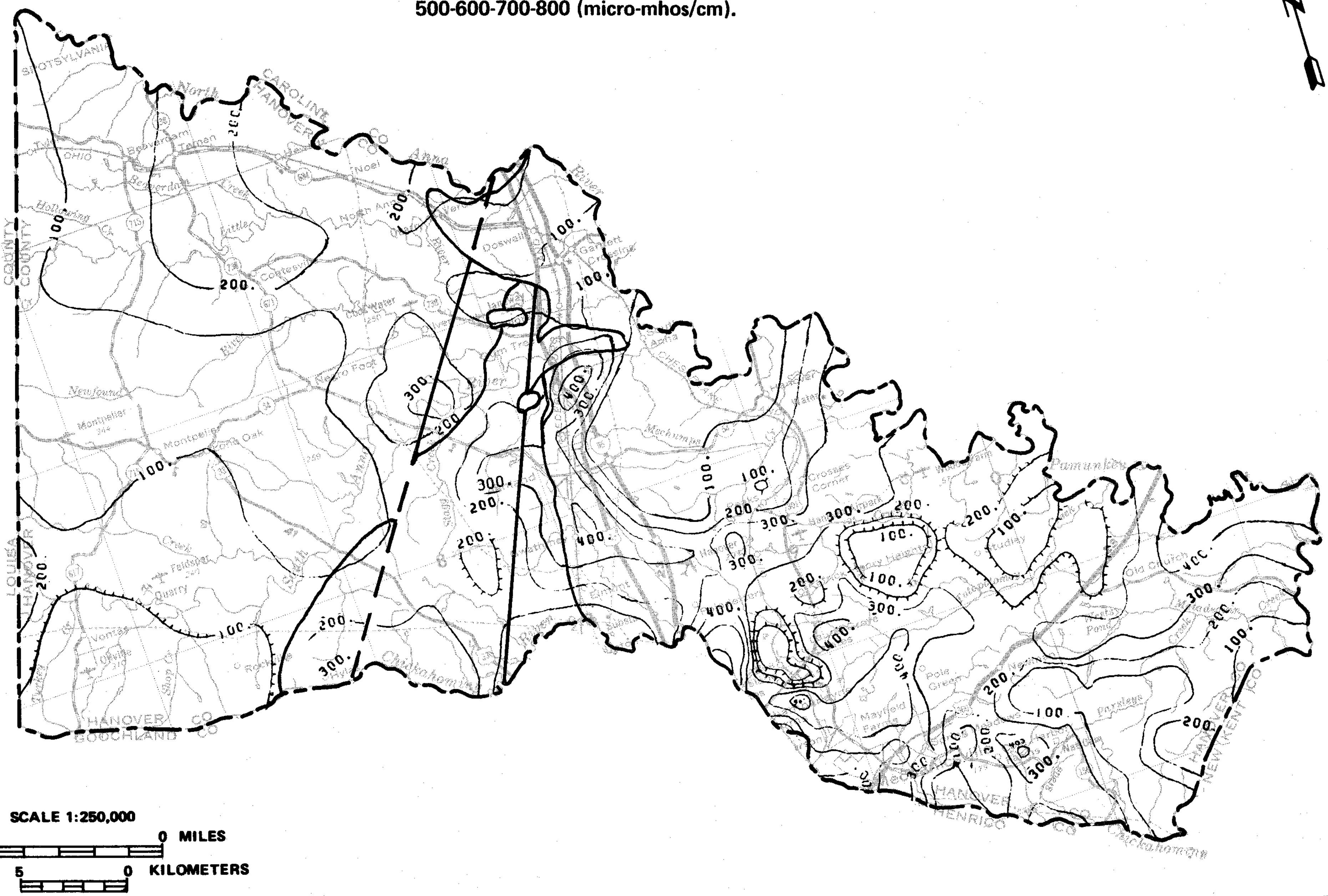
LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value

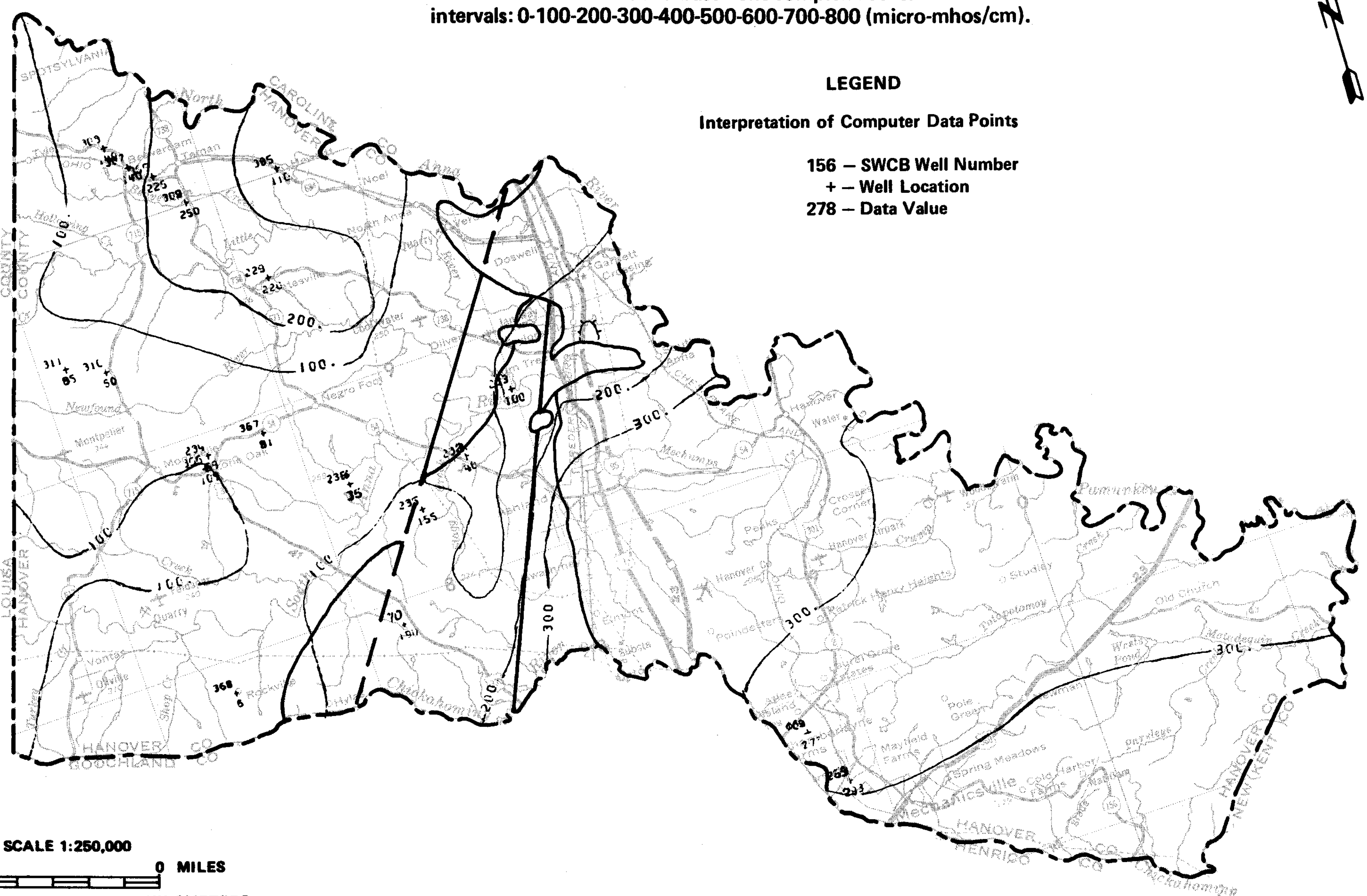
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 28a. Contour map showing specific conductance values for ground-water in Hanover County. Contour intervals:0-100-200-300-400-500-600-700-800 (micro-mhos/cm).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 28b. Contour map showing specific conductance values for ground-water in the Piedmont and basement complex rocks. Contour intervals: 0-100-200-300-400-500-600-700-800 (micro-mhos/cm).



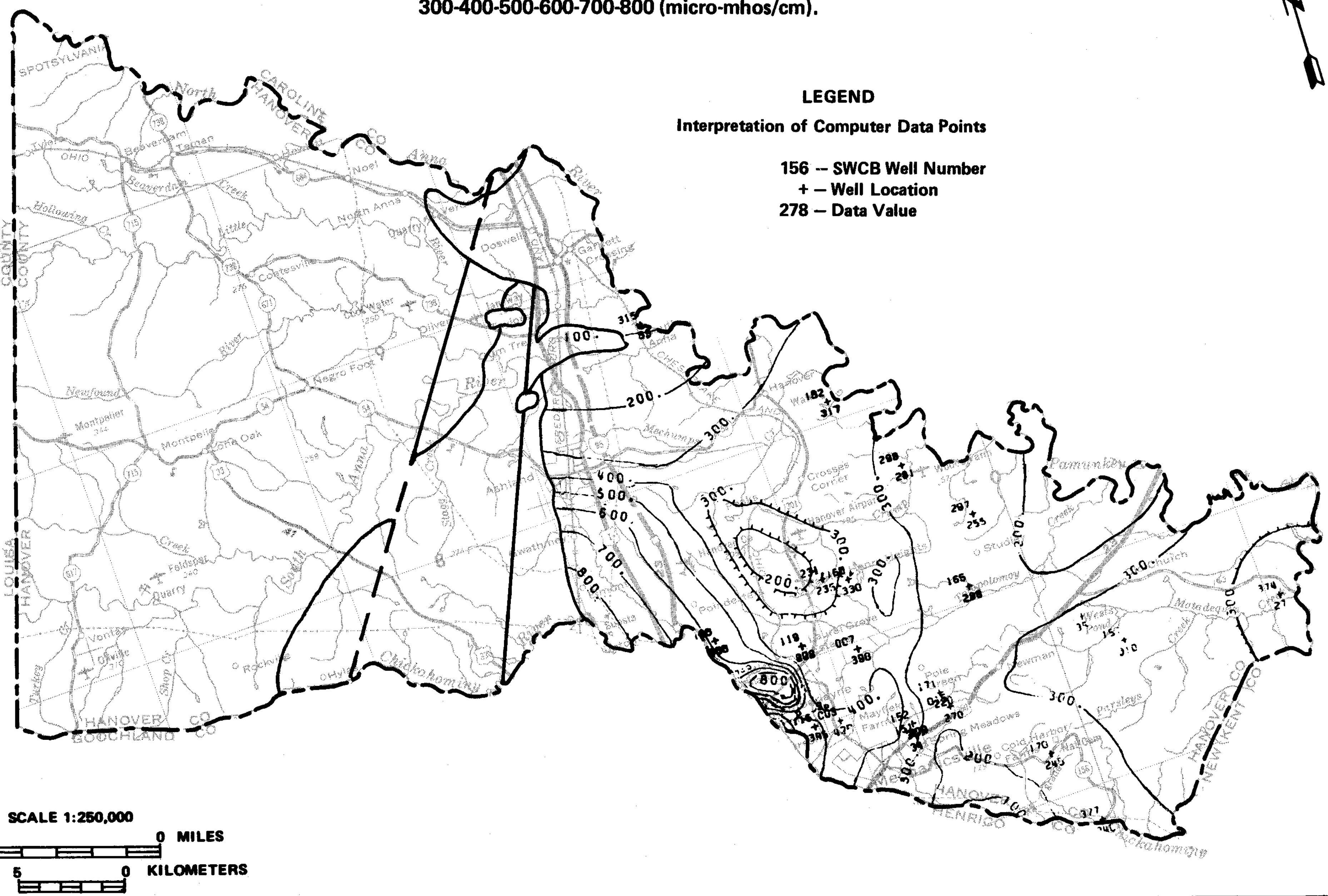
LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value

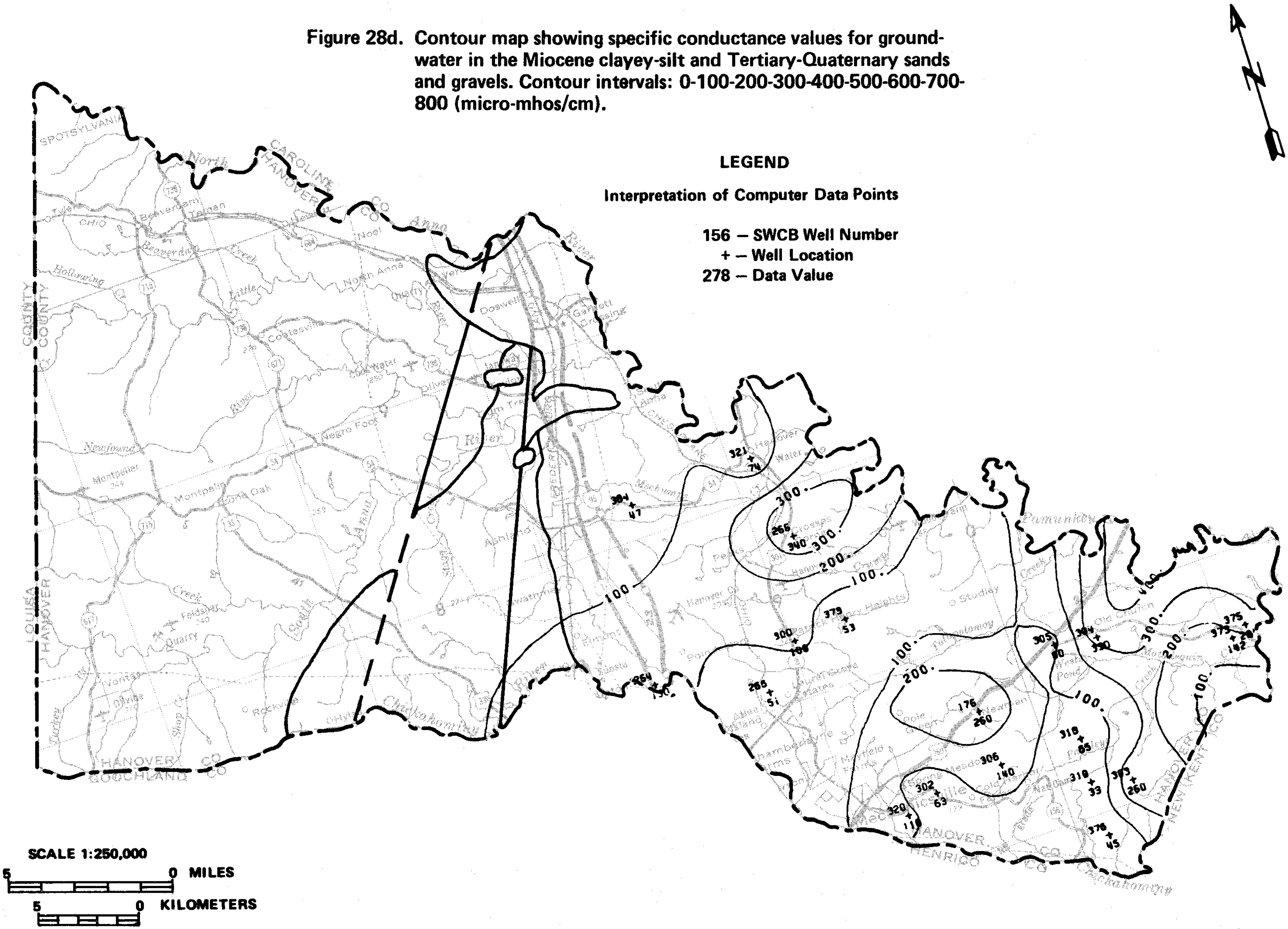
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP

Figure 28c. Contour map showing specific conductance values for ground-water in the Patuxent Formation. Contour intervals: 0-100-200-300-400-500-600-700-800 (micro-mhos/cm).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 28d. Contour map showing specific conductance values for ground-water in the Miocene clayey-silt and Tertiary-Quaternary sands and gravels. Contour intervals: 0-100-200-300-400-500-600-700-800 (micro-mhos/cm).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

before laboratory testing could be performed. In recent years, more efficient equipment has enabled expedient analysis, and this gives lower pH values.

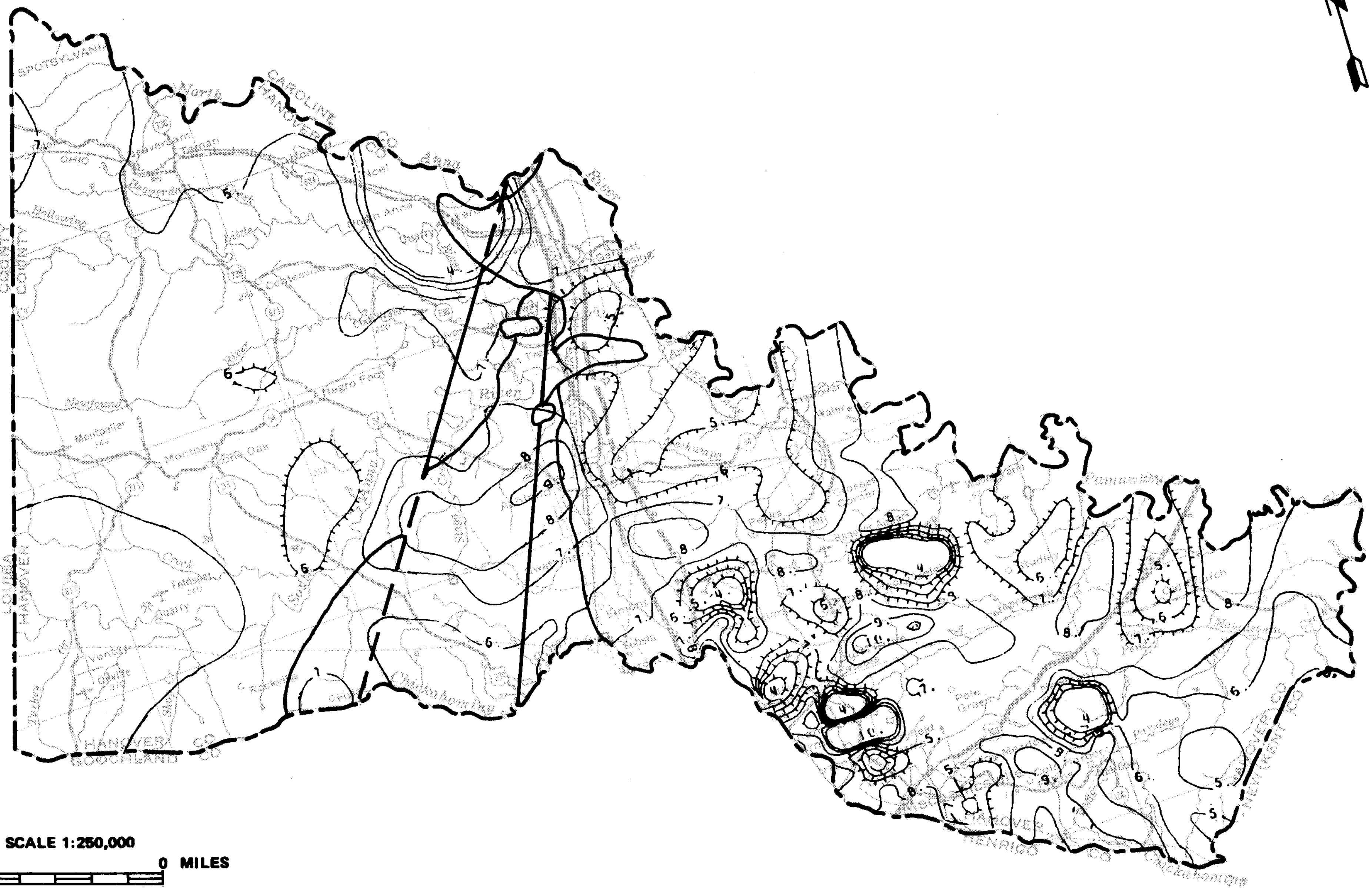
Common pH values for groundwater range from 5.5 to 8.5 (Figure 29a). The most basic (high pH) groundwater is noted at wells #8, 8.0 pH south of Craney Island Estates; #76, 8.5 off Route 156 east of Mechanicsville; and #260, 8.9 pH south of Newmans. The most acidic (low pH) groundwater is noted in wells #314, 4.5 pH just southeast of Taylorsville and #384, 4.9 pH on Route 54 just east of Interstate 95. Computer plots of pH values for the Piedmont and basement complex rocks, Patuxent, and Miocene clayey-silts and Tertiary-Quaternary sand and gravel aquifers are provided on Figures 29 b-d.

Total Dissolved Solids. The total dissolved solids values refer to the amount of dissolved (dissociated) substances contained in the water and are obtained by evaporating the water and weighing the residue or by totaling all of the ion concentrations. It is usually disagreeable to use groundwater with greater than 1000 ppm dissolved solids because of its taste and potential corrosive ability. Values this high can damage well screens and other well components. It is desirable to have water with less than 500 ppm dissolved solids to insure satisfactory domestic and industrial use.

The total dissolved solids contour map of Hanover County (Figure 30a) shows values of 100 ppm or less in most of the Piedmont section. Much of the remainder of the County has values between 100 ppm and 200 ppm with the exception of the Poindexters and Atlee areas where values from 400 to 600 ppm are noted. The wells with highest values include: well #8, 565 ppm south of Craney Island Estates; #10, 763 ppm at Craney Island Estates; #47, 453 ppm and 440 ppm south of Poindexters; and #198, 448 ppm and 466 ppm south of Poindexters. Contour maps of total dissolved solids values for the Piedmont and Basement Complex rocks, and the Patuxent aquifer, are provided on Figures 30b and 30c, respectively.

Iron (Fe^{++}). Iron is present in most water supplies, but in amounts above 0.3 ppm,staining of clothes and plumbing fixtures, as well as incrustation of well screens and pipes occurs. Some industries require

Figure 29a. Contour map showing pH values for groundwater in Hanover County. Contour intervals: 4-5-6-7-8-9-10 pH.



SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

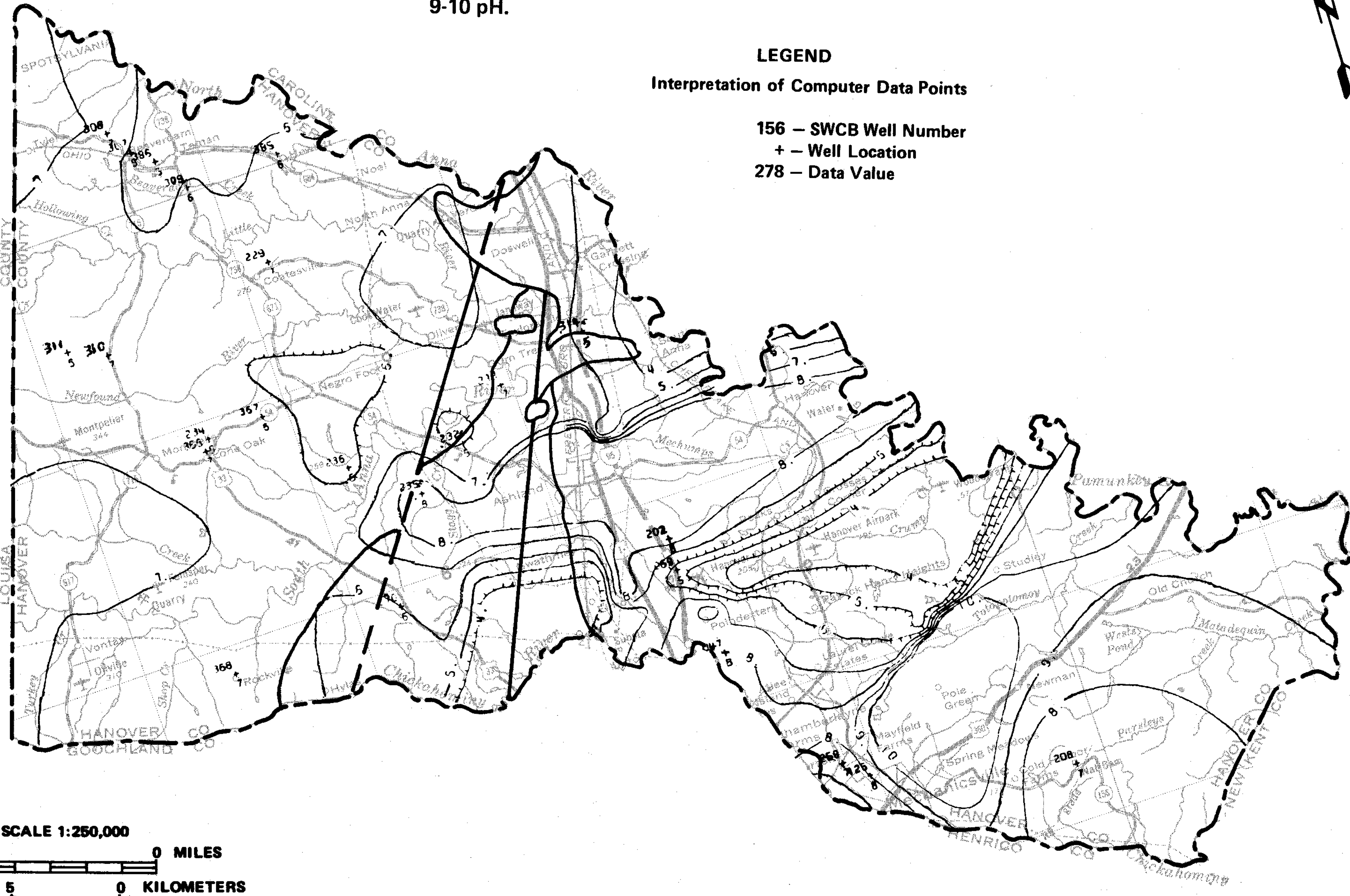
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 29b. Contour map showing pH values for groundwater in the Piedmont and basement complex rocks. Contour intervals: 4-5-6-7-8-9-10 pH.

LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
\+ – Well Location
278 – Data Value



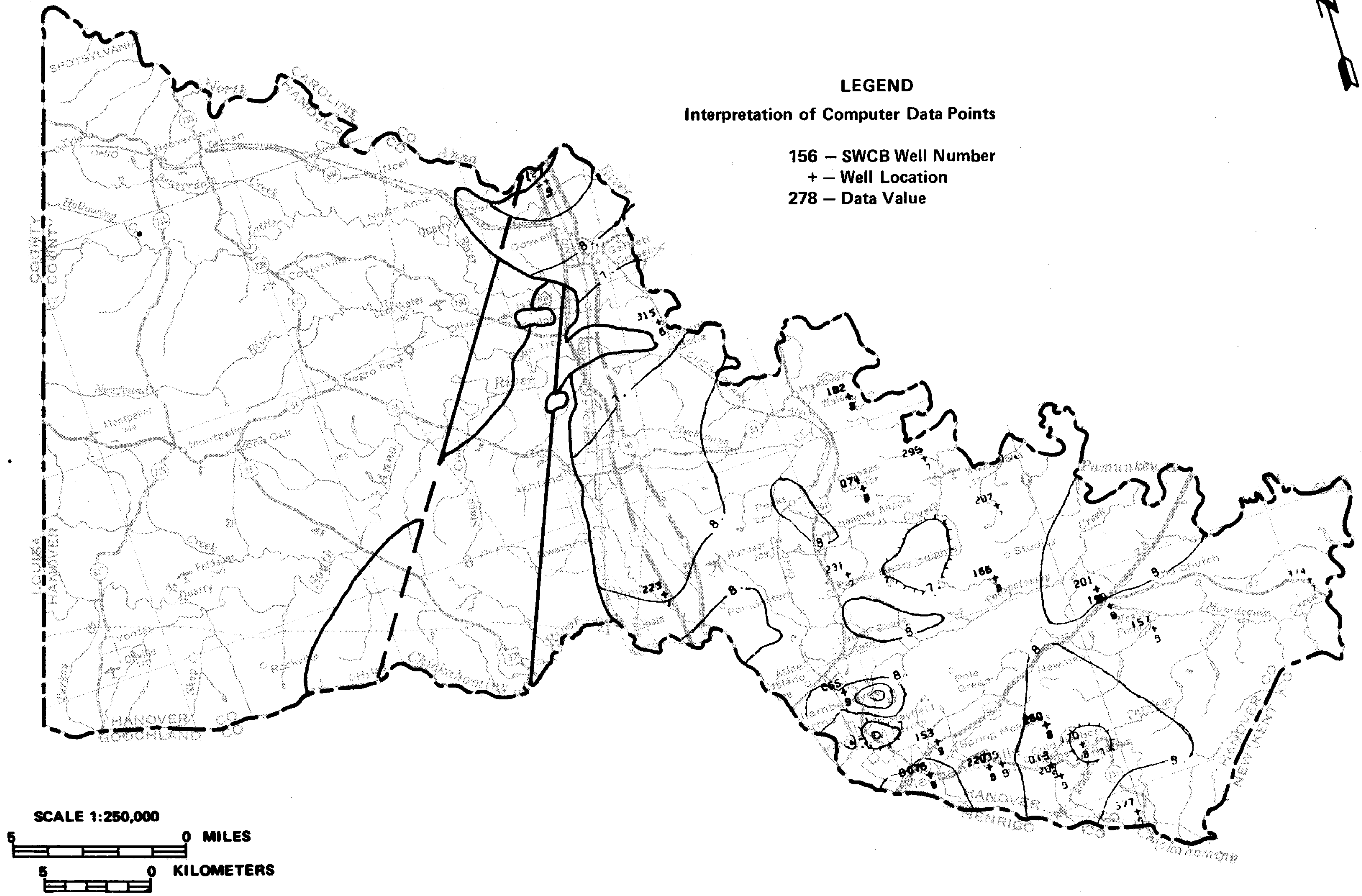
SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

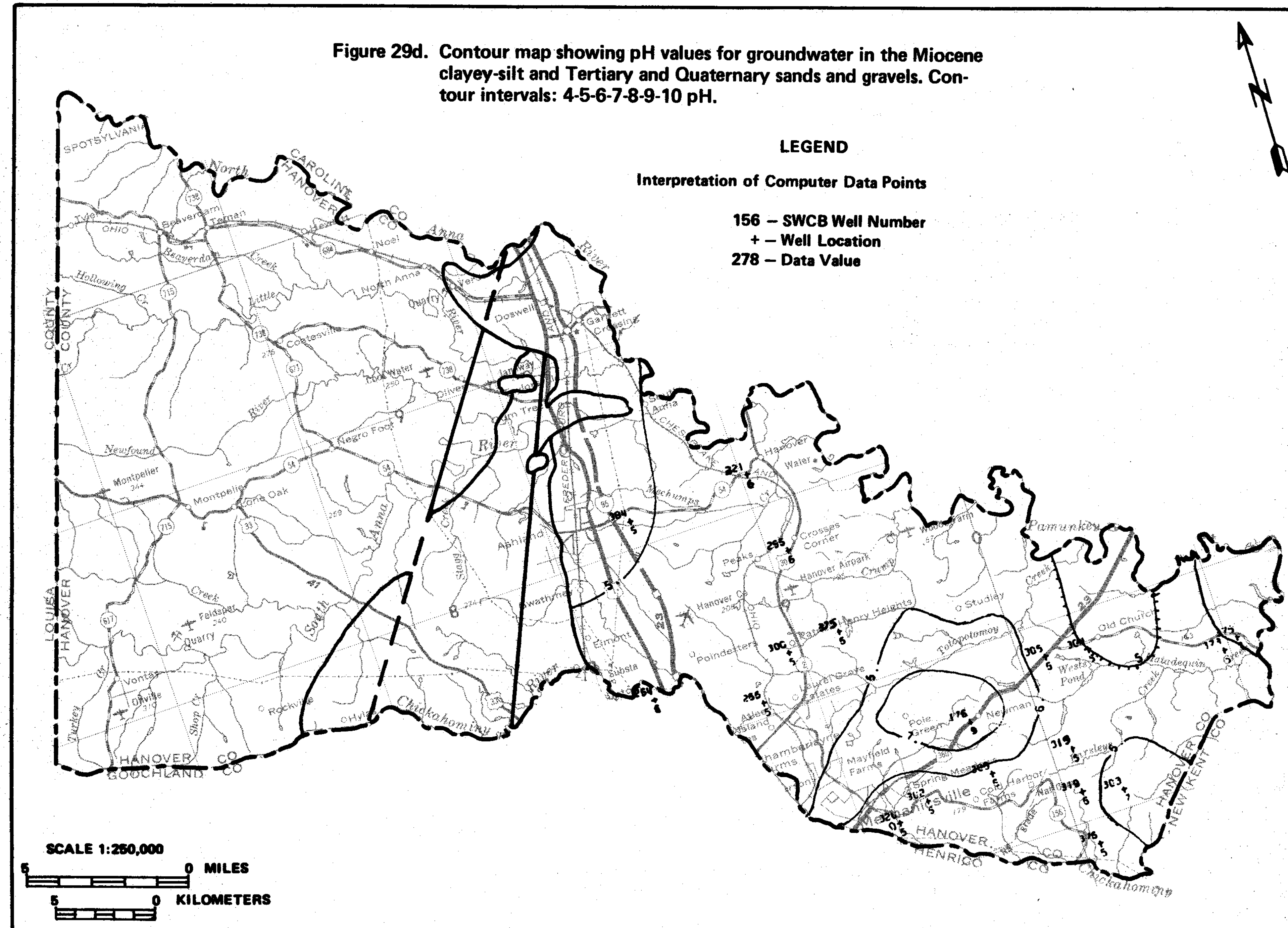
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 29c. Contour map showing pH values for groundwater in the Patuxent Formation. Contour intervals: 4-5-6-7-8-9-10 pH.



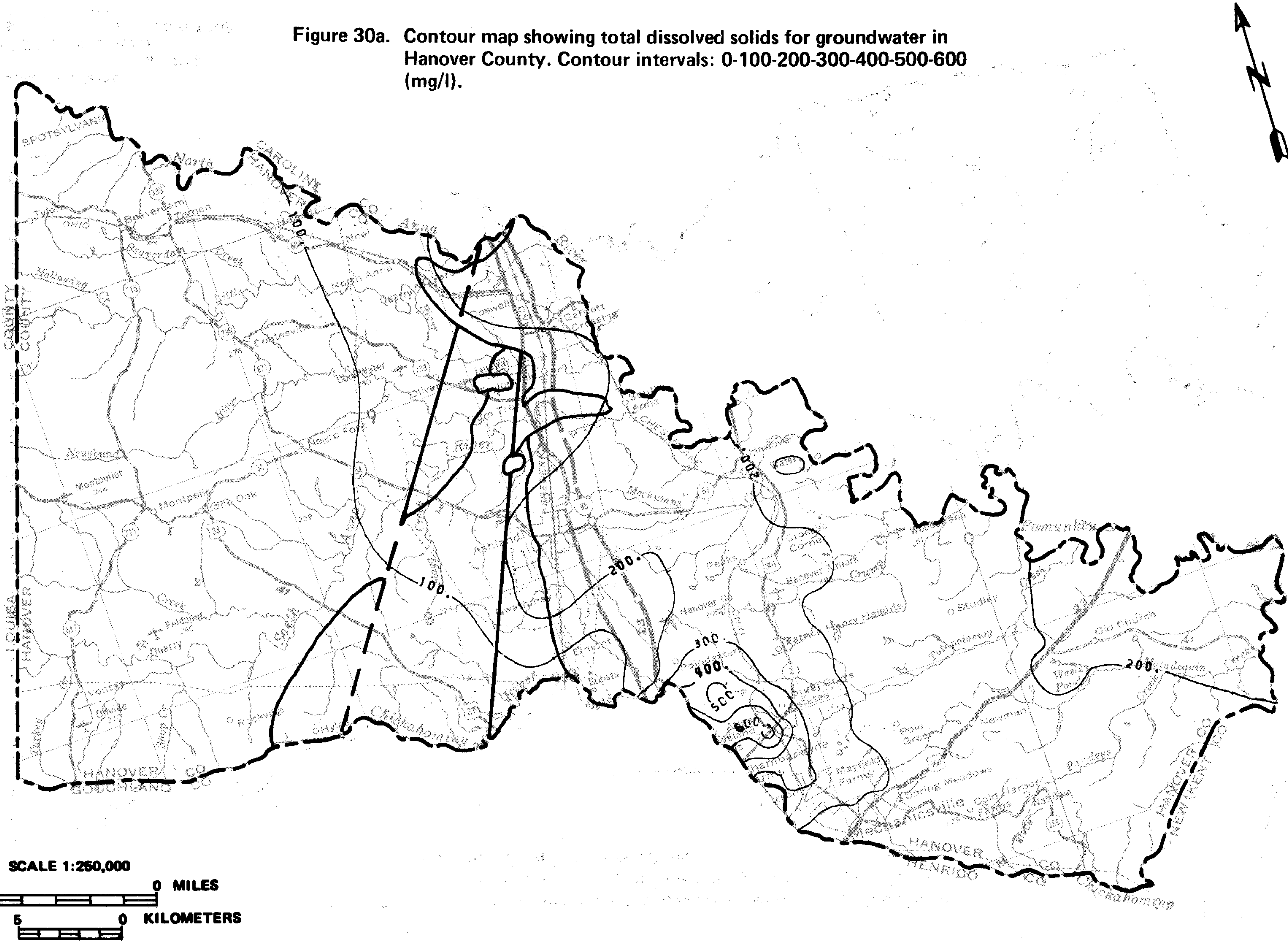
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 29d. Contour map showing pH values for groundwater in the Miocene clayey-silt and Tertiary and Quaternary sands and gravels. Contour intervals: 4-5-6-7-8-9-10 pH.



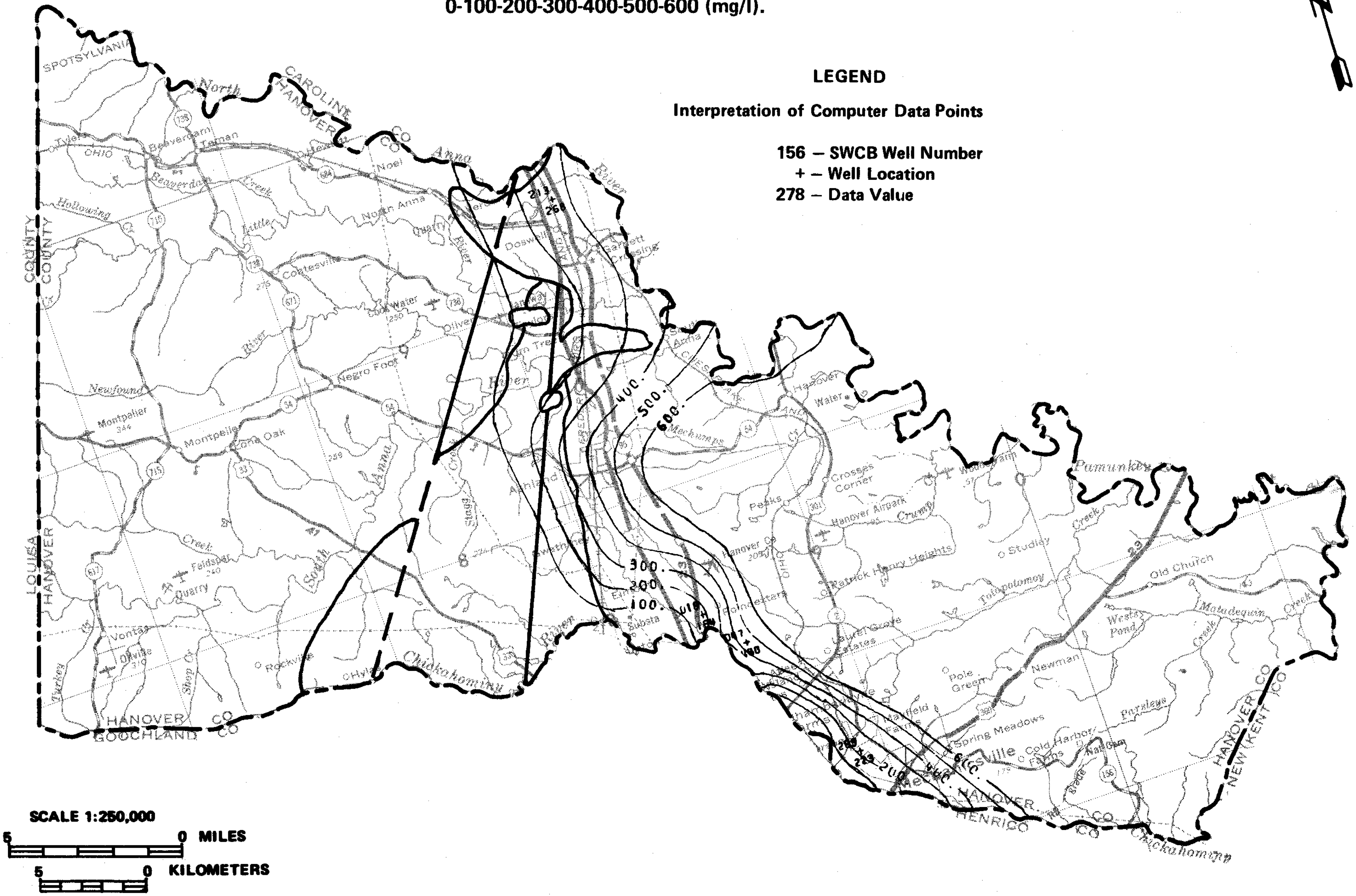
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 30a. Contour map showing total dissolved solids for groundwater in Hanover County. Contour intervals: 0-100-200-300-400-500-600 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 30b. Contour map showing total dissolved solids for groundwater in the Piedmont and basement complex Rocks. Contour intervals: 0-100-200-300-400-500-600 (mg/l).



LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value

SCALE 1:250,000

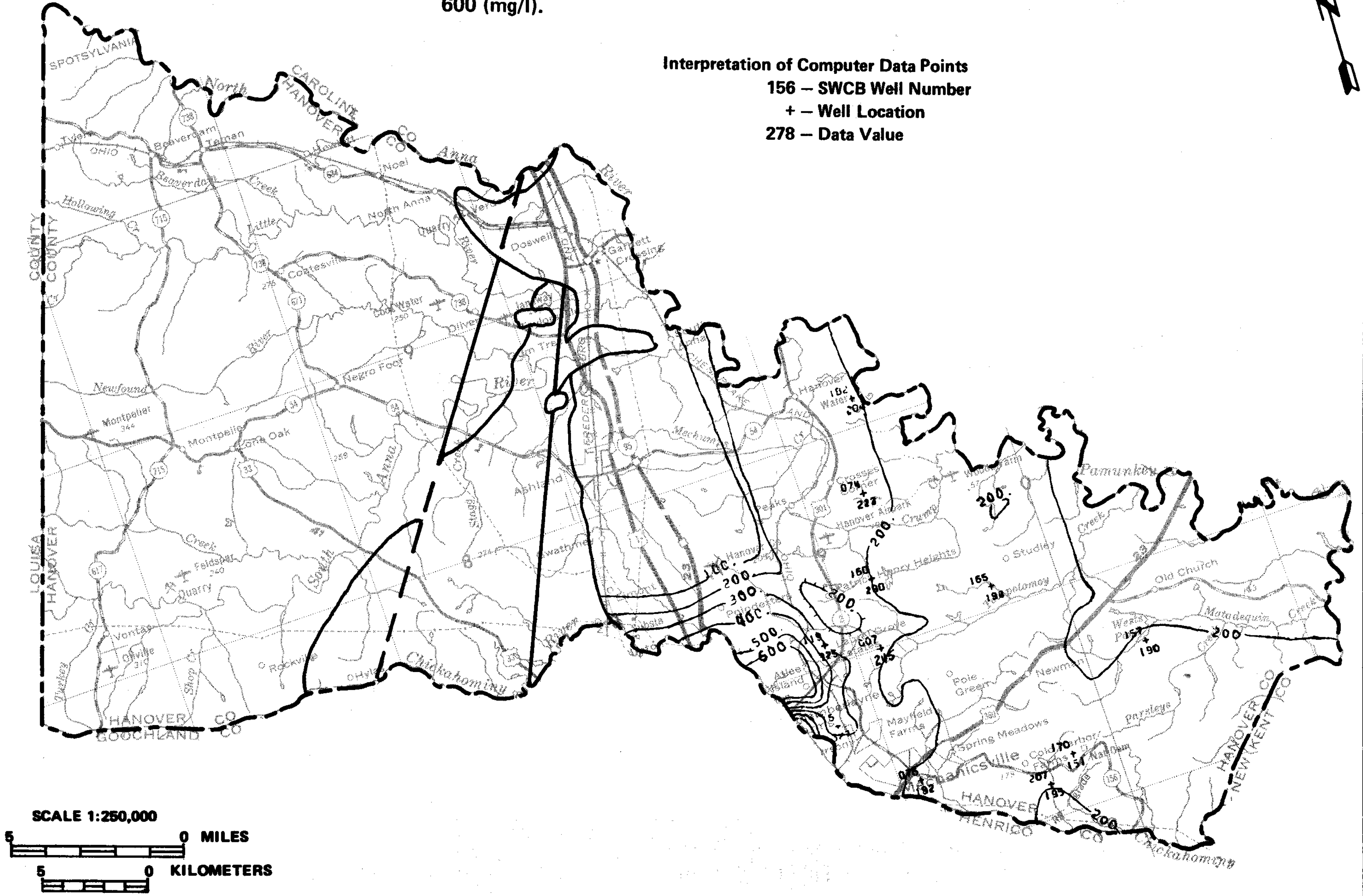
5 0 MILES

5 0 KILOMETERS

SOURCE: STATE WATER CONTROL BOARD – PRO, ADP

Figure 30c. Contour map showing total dissolved solids for groundwater in Patuxent Formation. Contour intervals: 0-100-200-300-400-500-600 (mg/l).

Interpretation of Computer Data Points
156 – SWCB Well Number
+ – Well Location
278 – Data Value



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

the iron concentration to be less than 0.1 ppm. This value is sometimes difficult to achieve since the average concentration in groundwater ranges from 1 to 5 ppm. Aeration usually can reduce this value to about 0.1 ppm. Physiologically, iron has no adverse affect on humans or animals. The human body actually requires 5 to 6 milligrams of iron per day.

Groundwater acquires iron from several iron-bearing minerals (biotite, hornblende, pyroxenes, and garnets) during the percolation process. Acidic and corrosive groundwater will dissolve the iron from well casing, piping, and pump parts. Iron-bearing groundwater may be clean when initially pumped, but upon contact with the oxygen of the air, an iron precipitate appears. Iron bacteria such as crenothrix flourish in iron bearing waters producing pipe clogging precipitates.

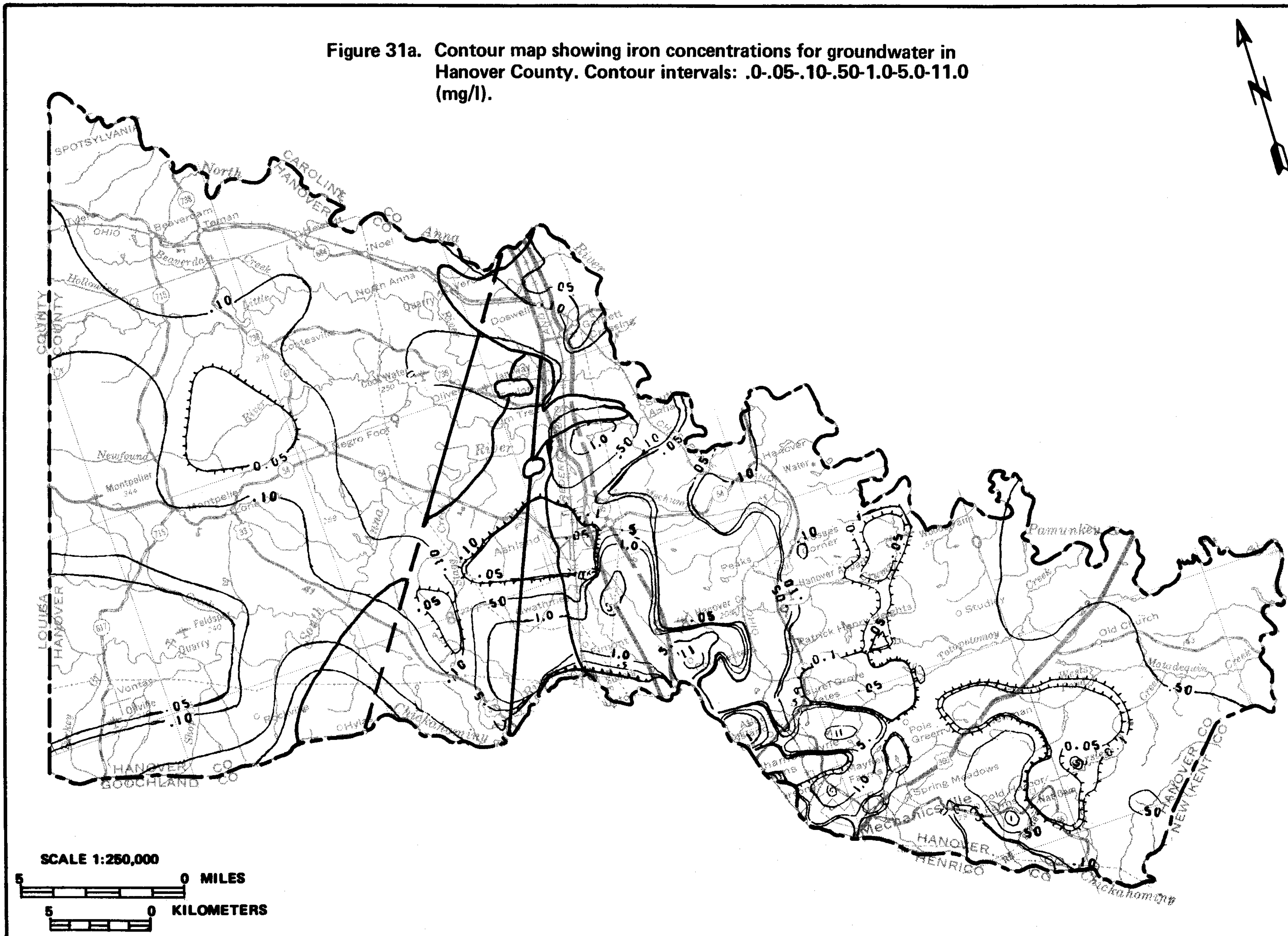
The groundwater-quality contour map of iron concentrations (Figure 31a) in Hanover County indicates lowest concentrations west of Ashland and east of Montpelier in the Piedmont section, and at Old Cold Harbor and northwest of Studley in the Coastal Plain. The most-concentrated areas are near the Fall Zone, notably near Poindexters and along Route 1 west of Lewistown.

Highest concentration wells include: well #18, 9.0 ppm at Interstate 95 and Route 656; #355, 7.0 ppm at Interstate 95 and Route 802; #197, 10.5 ppm and 4.97 ppm east of Borkey's Store off Route 606; and #369, 2.40 ppm near Hylas. Computer-drawn contours of iron values from the Piedmont and Basement Complex rocks, Patuxent and the Miocene clayey silt, and Tertiary and Quaternary sand and gravel aquifers, are shown on Figures 31b, 31c, and 31d, respectively.

Chloride (Cl^-). Sea water contains about 19,000 ppm of chloride, with rainwater and groundwater ranging from 1 to 5 ppm. Chloride amounts of less than 150 ppm are suitable for most uses. Municipalities usually require concentrations less than 250 ppm, with 350 ppm being objectionable for most industrial and irrigation purposes. A disagreeable taste occurs above 500 ppm. Livestock are able to drink water containing up to 4,000 ppm chloride.

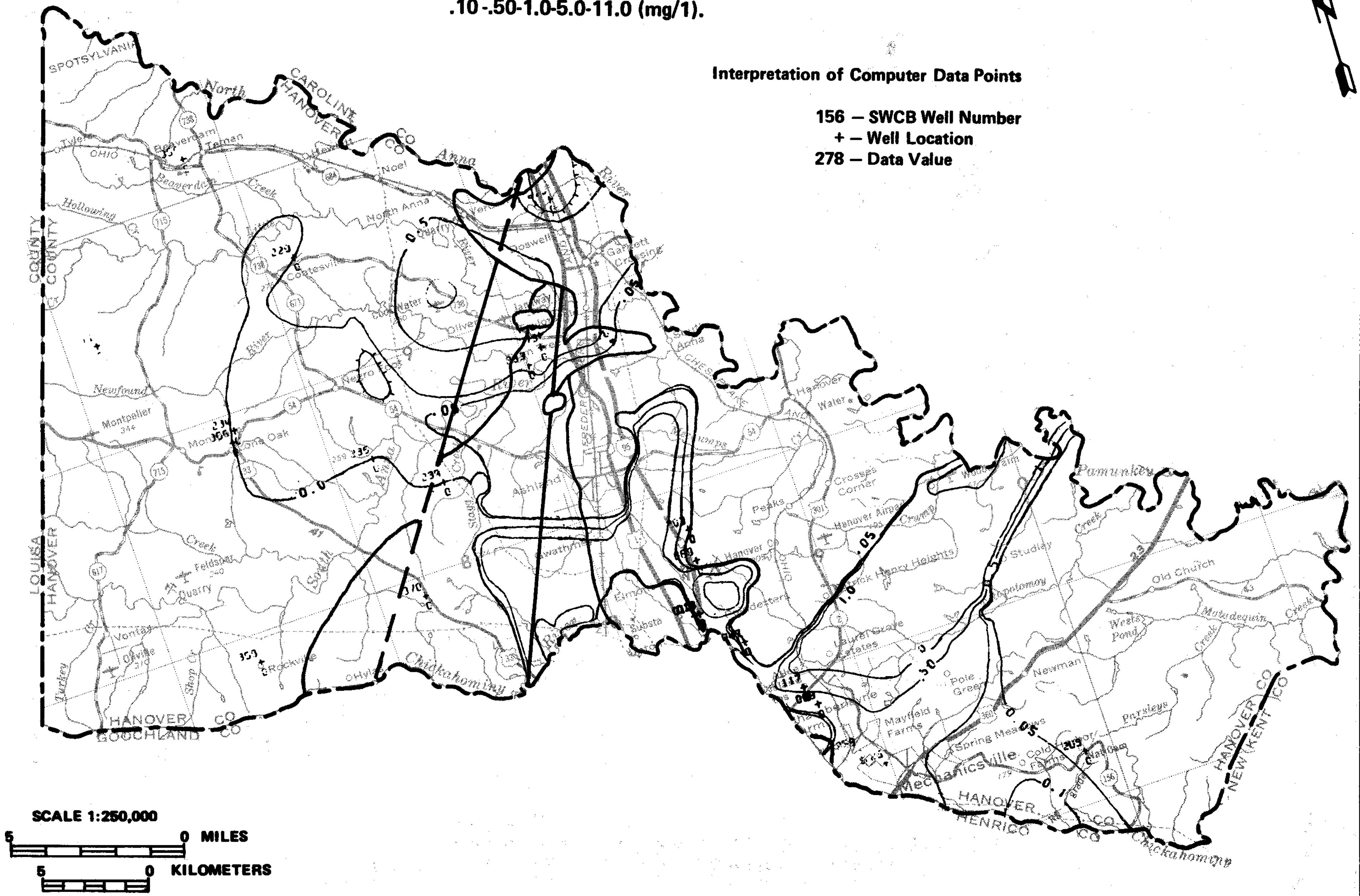
Chloride levels in Hanover County are commonly between 1 and 10 ppm (Figure 32a). Highest chloride concentrations are noted in Craney

Figure 31a. Contour map showing iron concentrations for groundwater in Hanover County. Contour intervals: .0-.05-.10-.50-1.0-5.0-11.0 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 31b. Contour map showing iron values for groundwater in the Piedmont and basement complex rocks. Contour intervals: 0-.05-.10-.50-1.0-5.0-11.0 (mg/1).



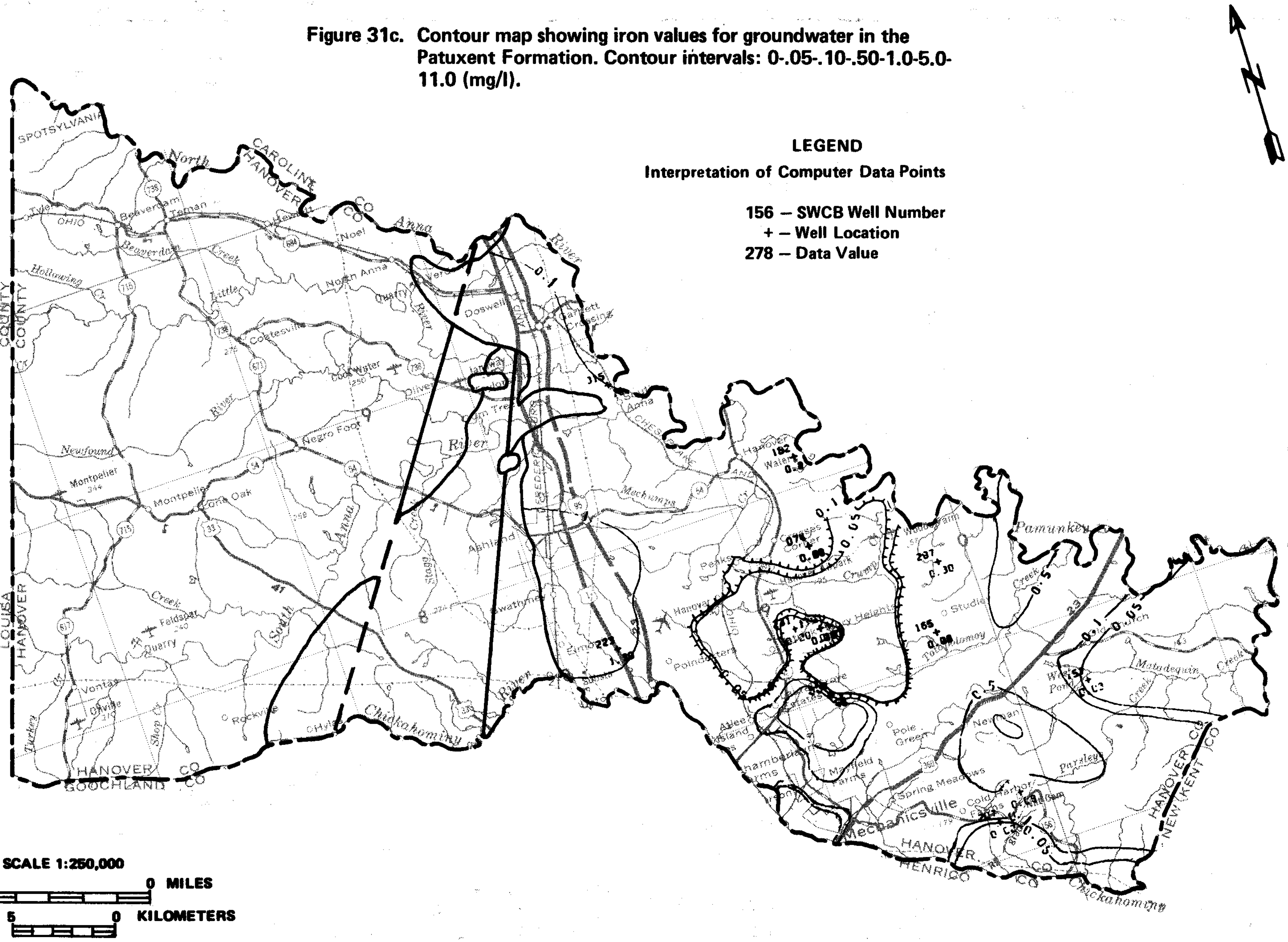
Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value

SCALE 1:250,000
5 0 MILES
5 0 KILOMETERS

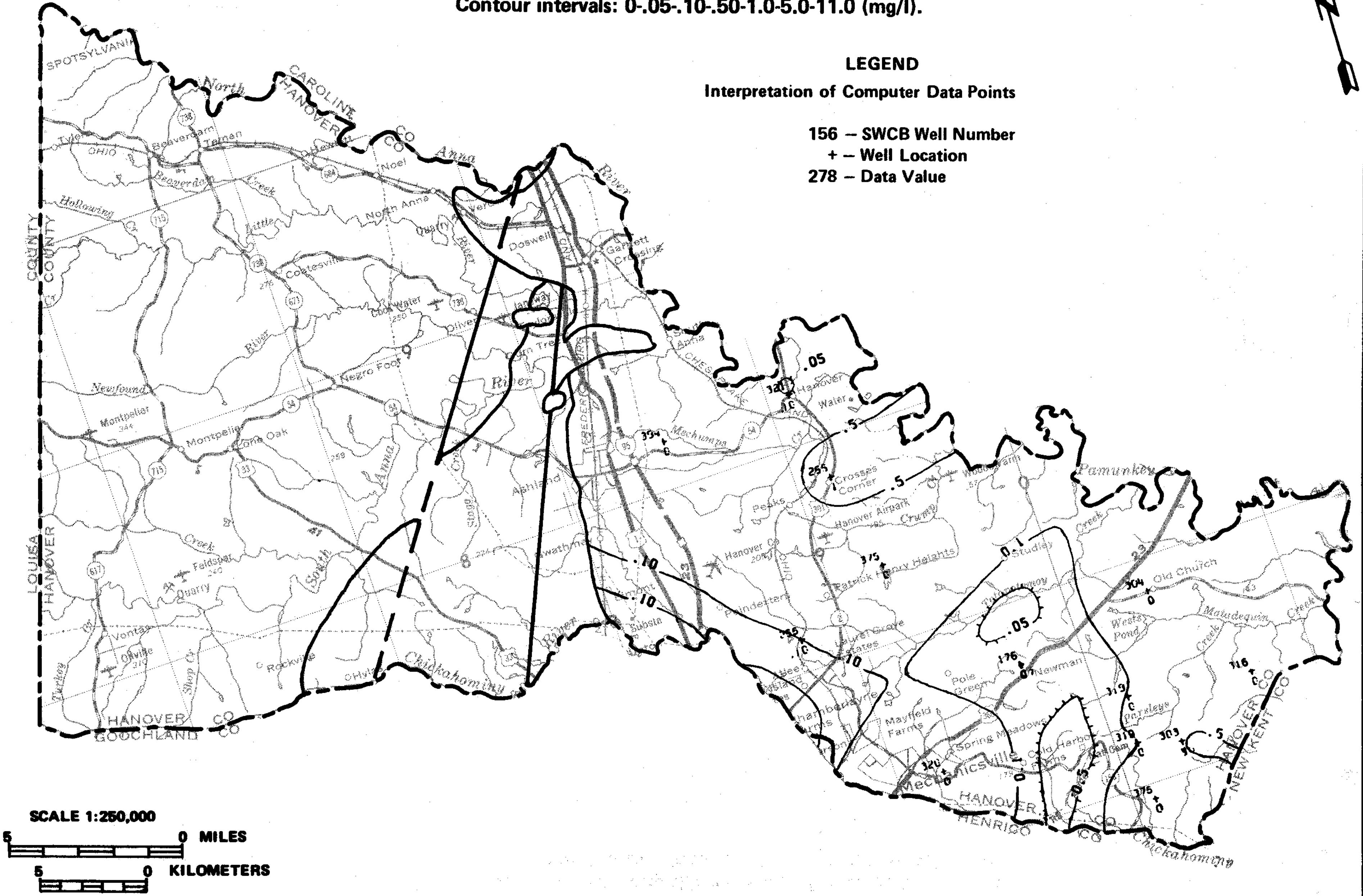
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP

Figure 31c. Contour map showing iron values for groundwater in the Patuxent Formation. Contour intervals: 0-.05-.10-.50-1.0-5.0-11.0 (mg/l).



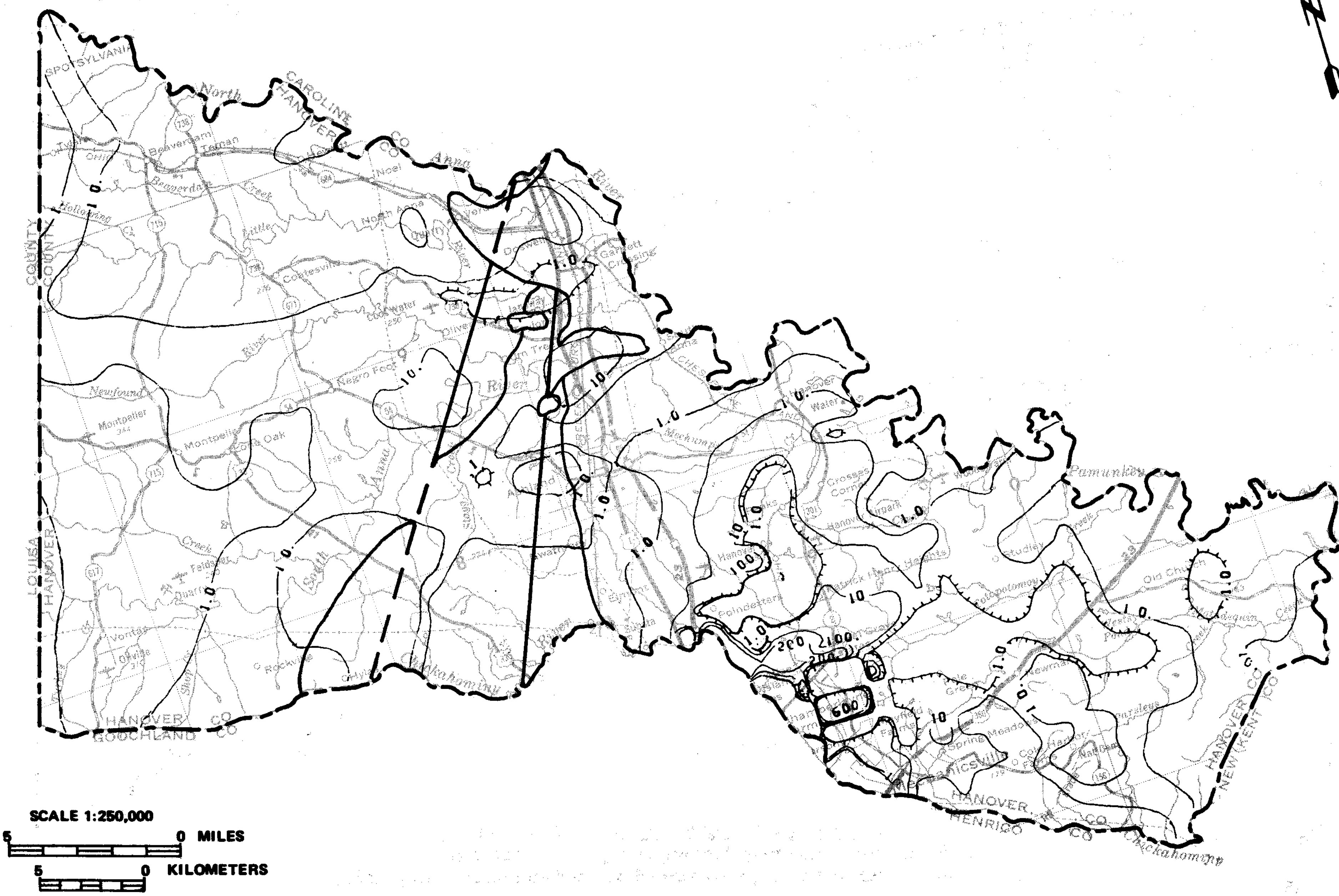
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 31d. Contour map showing iron values for groundwater in the Miocene clayey-silt and Tertiary-Quaternary sands and gravels. Contour intervals: 0-.05-.10-.50-1.0-5.0-11.0 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 32a. Contour map showing chloride values for groundwater in Hanover County. Contour intervals: 0-1.0-10-100-200-600 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Island Estates (well #10) with a value of 544 ppm sampled in 1965. Other high concentration wells include: well #119, 320.1 ppm and 321 ppm near Laurel Grove Estates; #125, 205.3 ppm north of Mechanicsville; and #265, 103 ppm at Crosses Corner. The Coastal Plain (Patuxent Aquifer) yields some of the highest chloride values (10 to 200 ppm). The Piedmont rocks and saprolite consistently have values less than 10 ppm. Computer-drawn contours of chloride values from the Piedmont and basement complex rocks, Patuxent, and Miocene clayey silt and Tertiary-Quaternary sand and gravel aquifers are on Figures 32b-d.

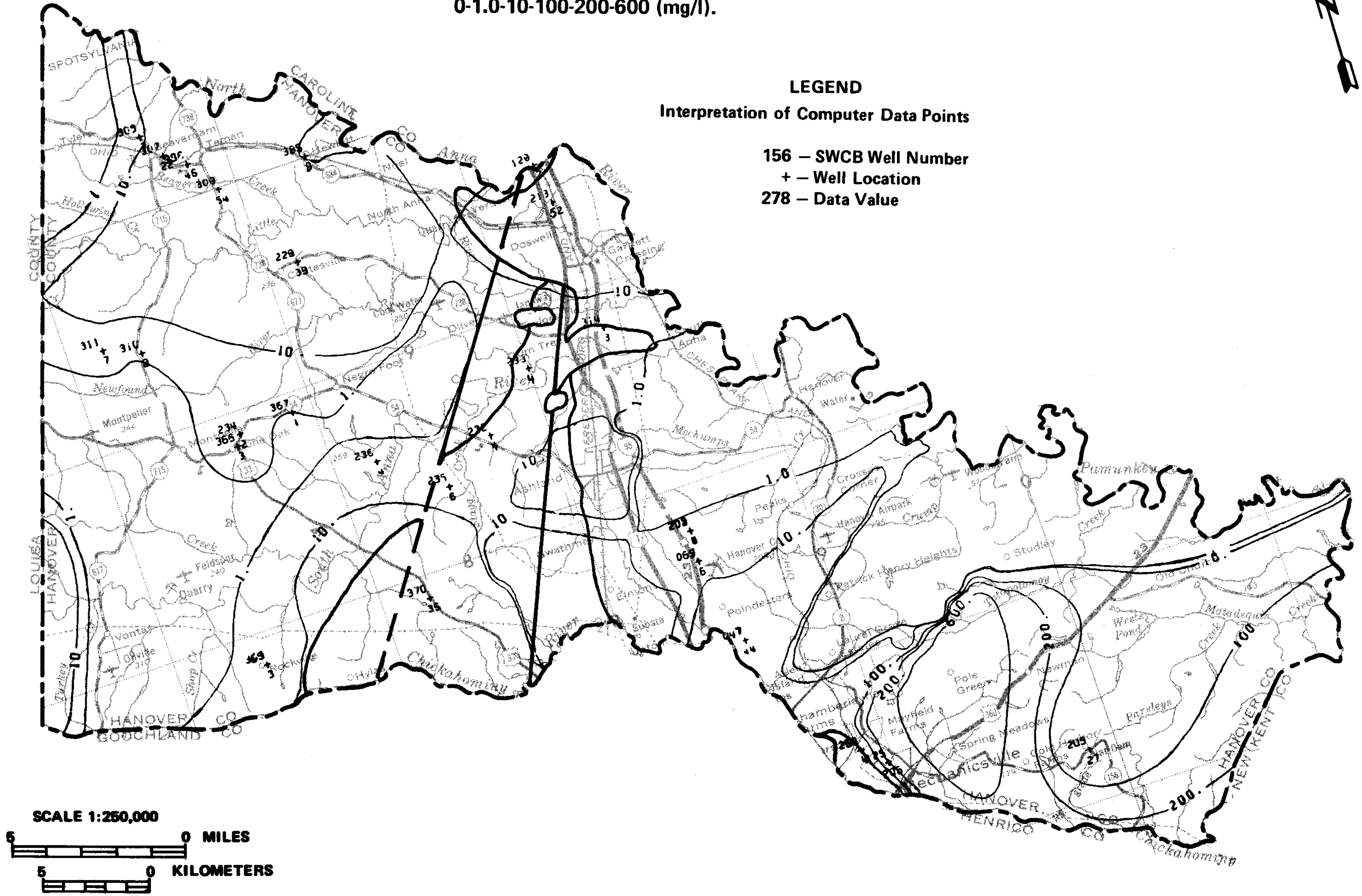
Fluoride (F^-). Fluoride in groundwater is usually derived from the mineral fluorite (CaF_2) associated as a later-hydrothermal mineral in cavities and joints in granites and pegmatites. Some fluoride may come from micas and clays that have had (OH^-) groups replaced by (F^-). High fluoride concentrations can cause mottling of children's teeth. Mottling can occur at fluoride levels above 0.8 ppm. Adults can tolerate levels of 3 to 4 ppm without ill effects. Some fluoride is desirable in the prevention of tooth decay, with 1.0 ppm chosen as the ideal concentration.

Fluoride in Hanover County varies from 0.5 ppm to 8.5 ppm (Figure 33a). The highest-concentration areas are north of Ellerson and east of Atlee. Wells with the highest values are well #8, 3.4 ppm south of Craney Island Estates; #10, 8.5 ppm at Craney Island Estates; #12, 2.0 ppm southeast of Poindexters; #119, 2.6 ppm near Laurel Grove Estates; and #125, 2.6 ppm north of Mechanicsville. The rest of the County, both Piedmont and Coastal Plain, have concentrations near 0.5 ppm. Computer-drawn contours of fluoride values from the Piedmont and basement complex and the Patuxent aquifers are shown on Figures 33b and 33c.

Nitrate (NO_3^-). Nitrate can vary greatly in groundwaters, with little or no relationship to the surrounding geology or the groundwater aquifer. Most nitrates are derived from the soil zone: nitrogen-fixing bacteria, fertilizer, manure, and plant debris.

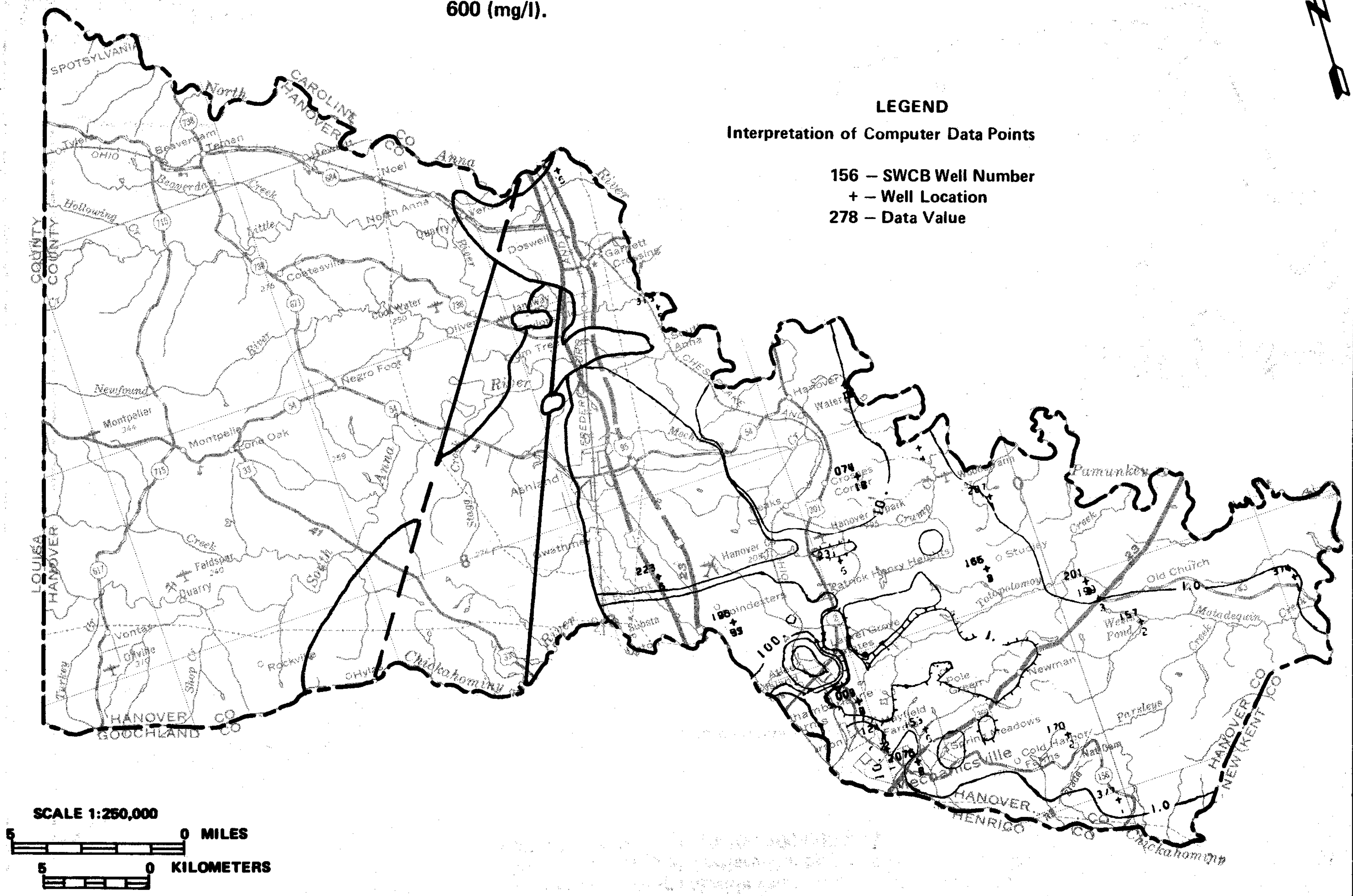
Concentrations greater than 45 ppm may cause a toxic effect called "cyanosis" in young infants. Cyanosis does not occur in older children and adults. A maximum value of 45 ppm nitrate or 10 ppm nitrogen is the healthful limit determined by the State Health Department.

Figure 32b. Contour map showing chloride concentrations for groundwater in the Piedmont and basement complex. Contour intervals: 0-1.0-10-100-200-600 (mg/l).



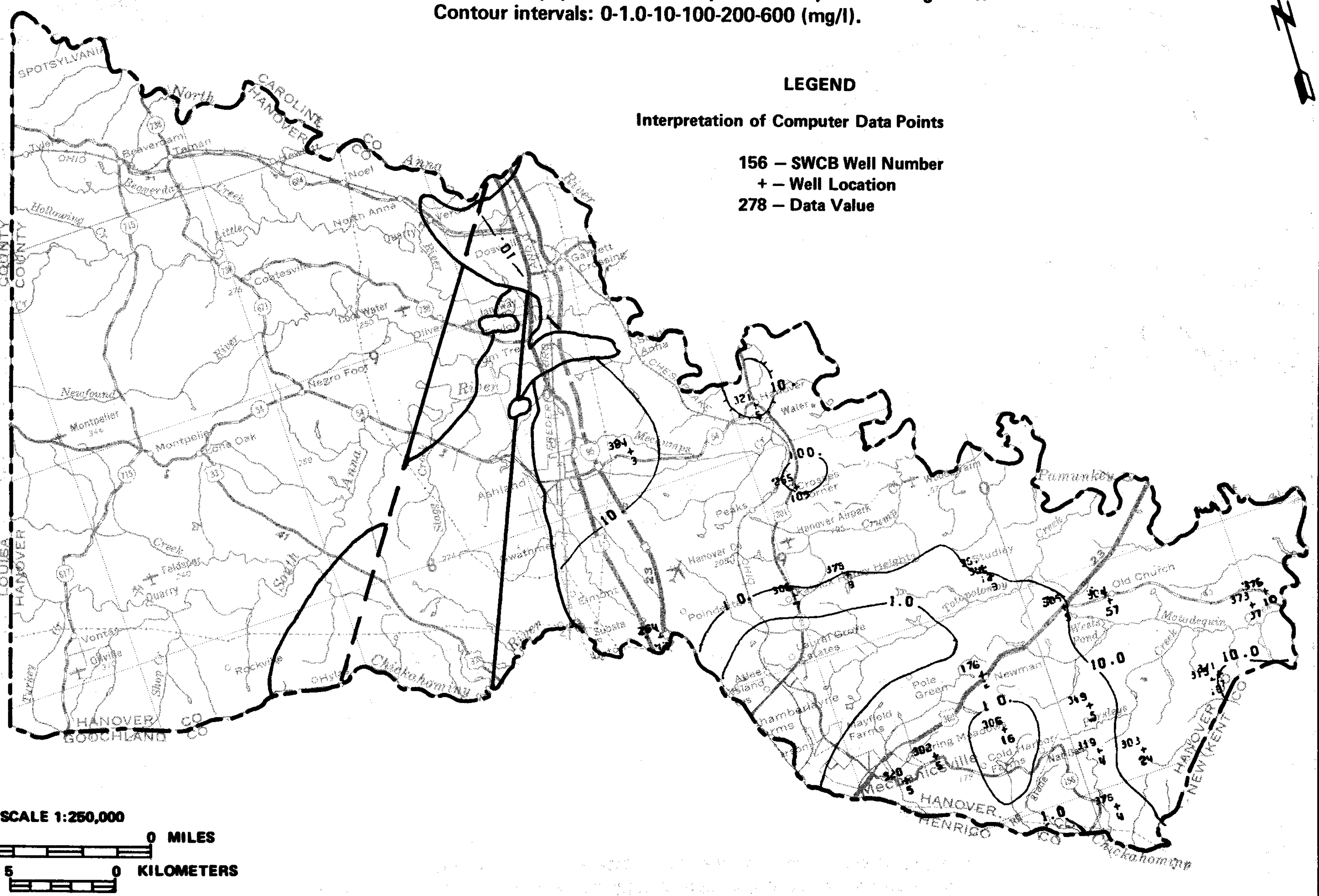
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 32c. Contour map showing chloride concentrations for groundwater in the Patuxent Formation. Contour intervals: 0-1.0-10-100-200-600 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 32d. Contour map showing chloride values for groundwater in the Miocene clayey-silt and Tertiary-Quaternary sands and gravels. Contour intervals: 0-1.0-10-100-200-600 (mg/l).



LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value

SCALE 1:250,000

5 0 MILES

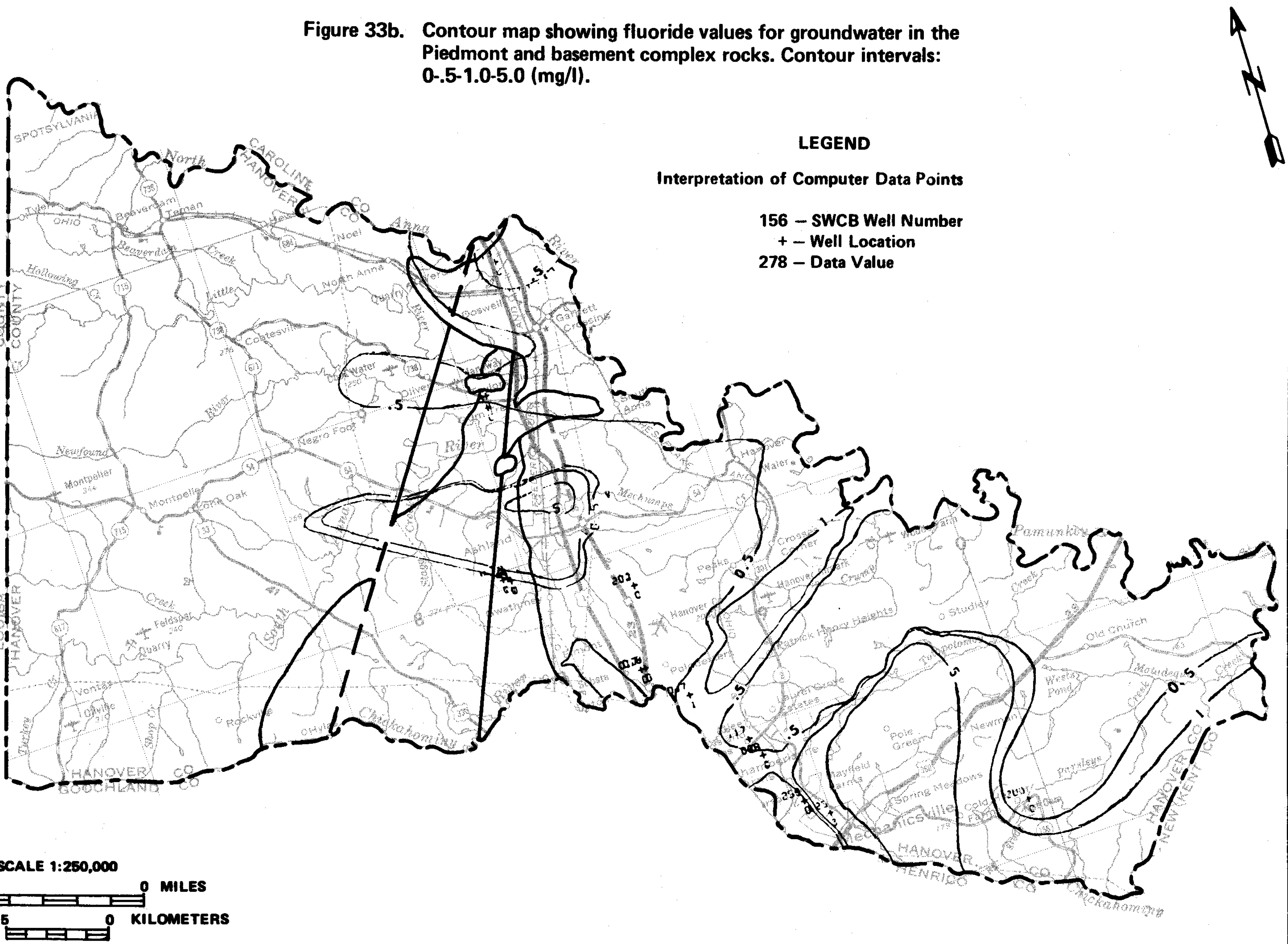
5 0 KILOMETERS

SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 33a. Contour map showing fluoride values for groundwater in Hanover County. Contour intervals: 0-.5-1.0-5.0 (mg/l).

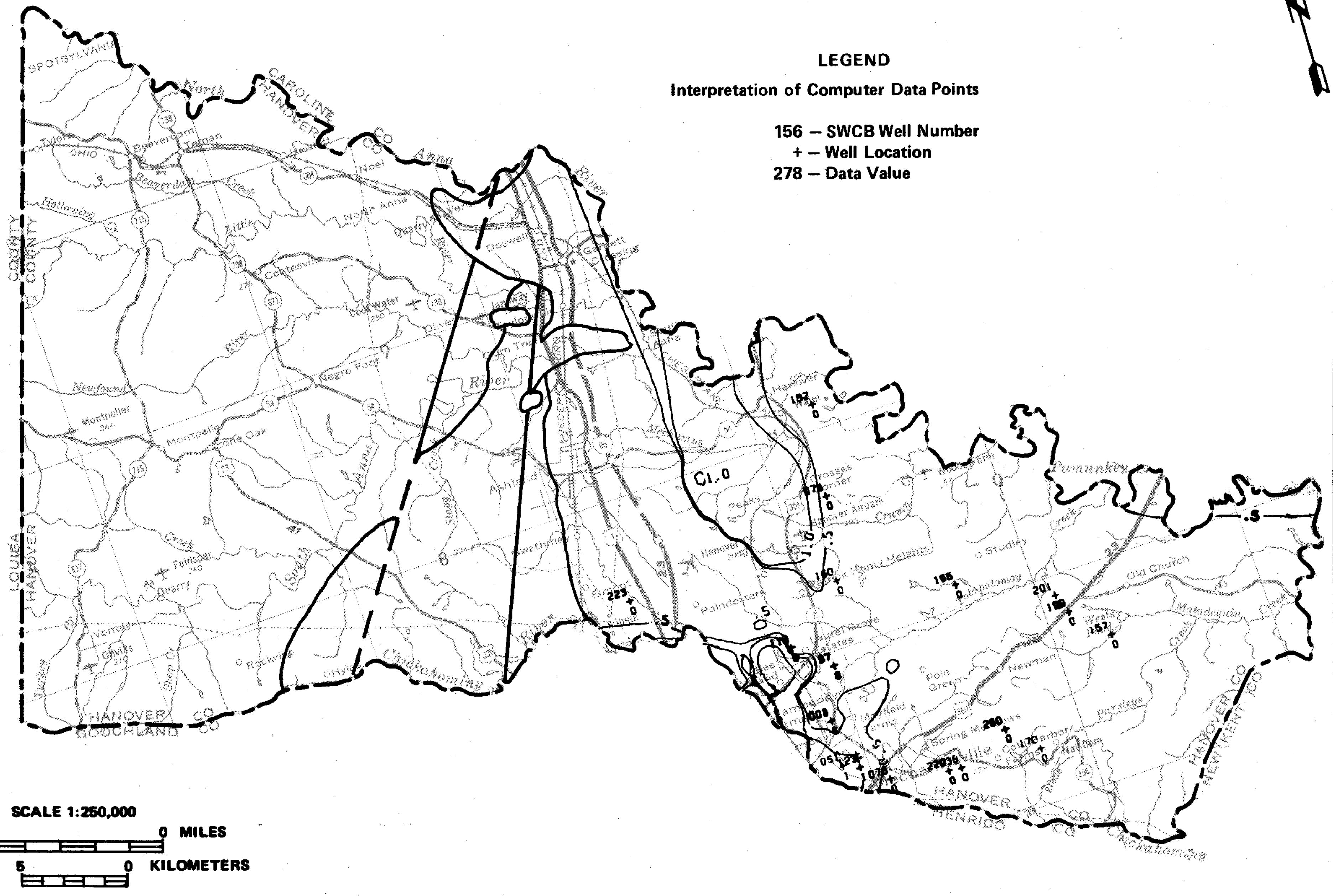
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 33b. Contour map showing fluoride values for groundwater in the Piedmont and basement complex rocks. Contour intervals: 0-.5-1.0-5.0 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 33c. Contour map showing fluoride values for groundwater in the Patuxent Formation. Contour intervals: 0-.5-1.0-5.0 (mg/1).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

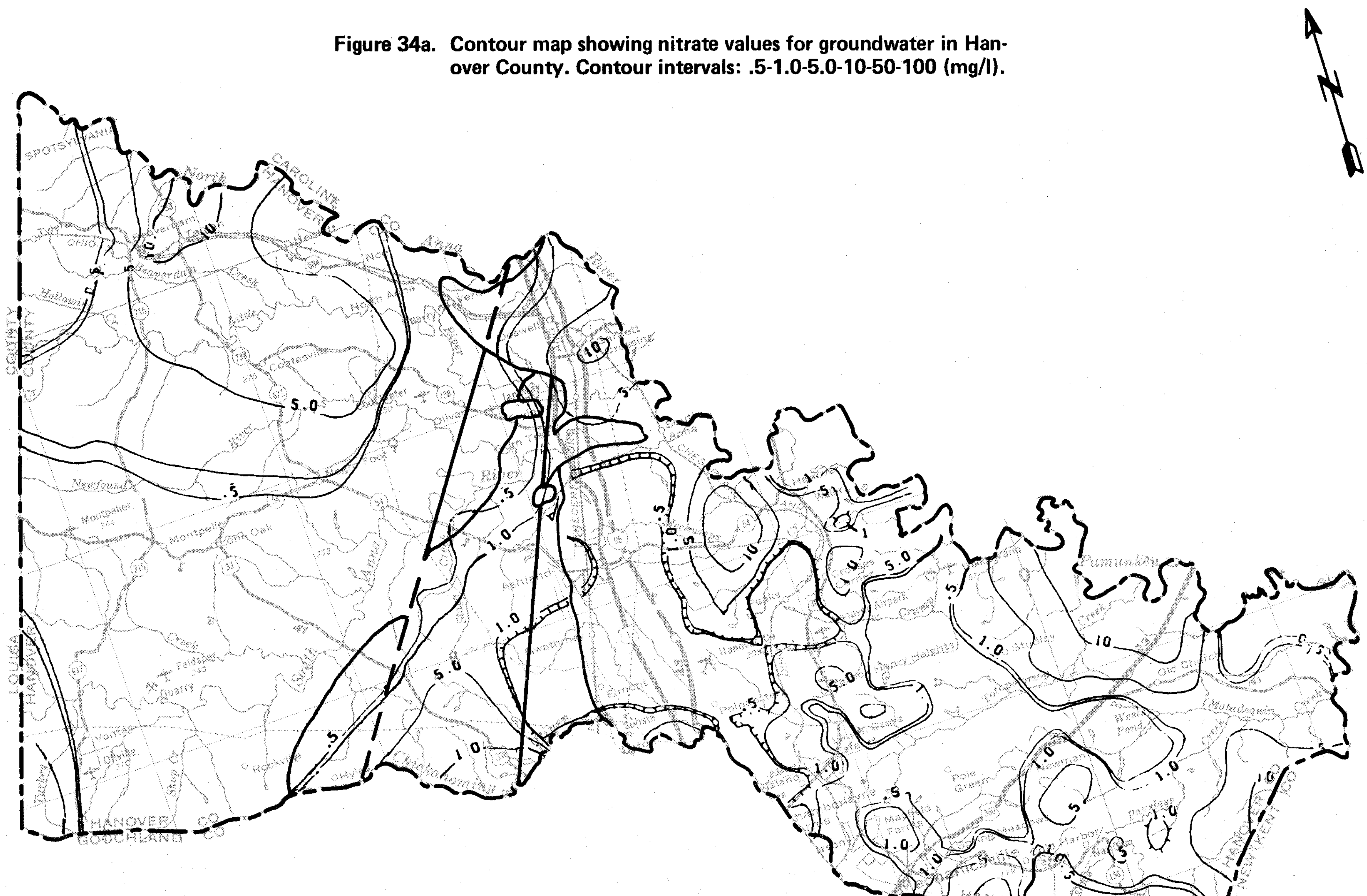
Nitrates in groundwater samples from Hanover County differ greatly. The groundwater quality contour map (Figure 34a) indicates highest levels at wells #264, 46.5 ppm on Route 1 near the southern border of the County; #382, 57.6 ppm west of Hanover Courthouse, and #386, 57.6 ppm near Beaverdam. These high levels possibly are caused by septic tank drainfield seepage in the vicinity of the wells. Computer-drawn contours of nitrate values from the Piedmont and basement complex rocks, Patuxent, and Miocene clayey silt and Tertiary-Quaternary sands and gravels aquifers are shown on Figures 34b-d.

Conclusions

Groundwater quality in Hanover County is generally quite good. Several areas have unusually-high values of certain ion concentrations, but these concentrations are rarely a health hazard and usually are caused by the chemical composition of the subsurface aquifers.

It becomes apparent that the quality of all groundwater must be maintained at its naturally-high standard. Groundwater pollution is usually impossible to clean up, and, therefore, prevention of pollution is the only viable recourse. The groundwater quality information presented here should be utilized by the public not only to avoid areas of poor quality groundwater, but also to familarize the public with various kinds of natural and man-made contaminants affecting our fragile groundwater resources.

Figure 34a. Contour map showing nitrate values for groundwater in Hanover County. Contour intervals: .5-1.0-5.0-10-50-100 (mg/l).



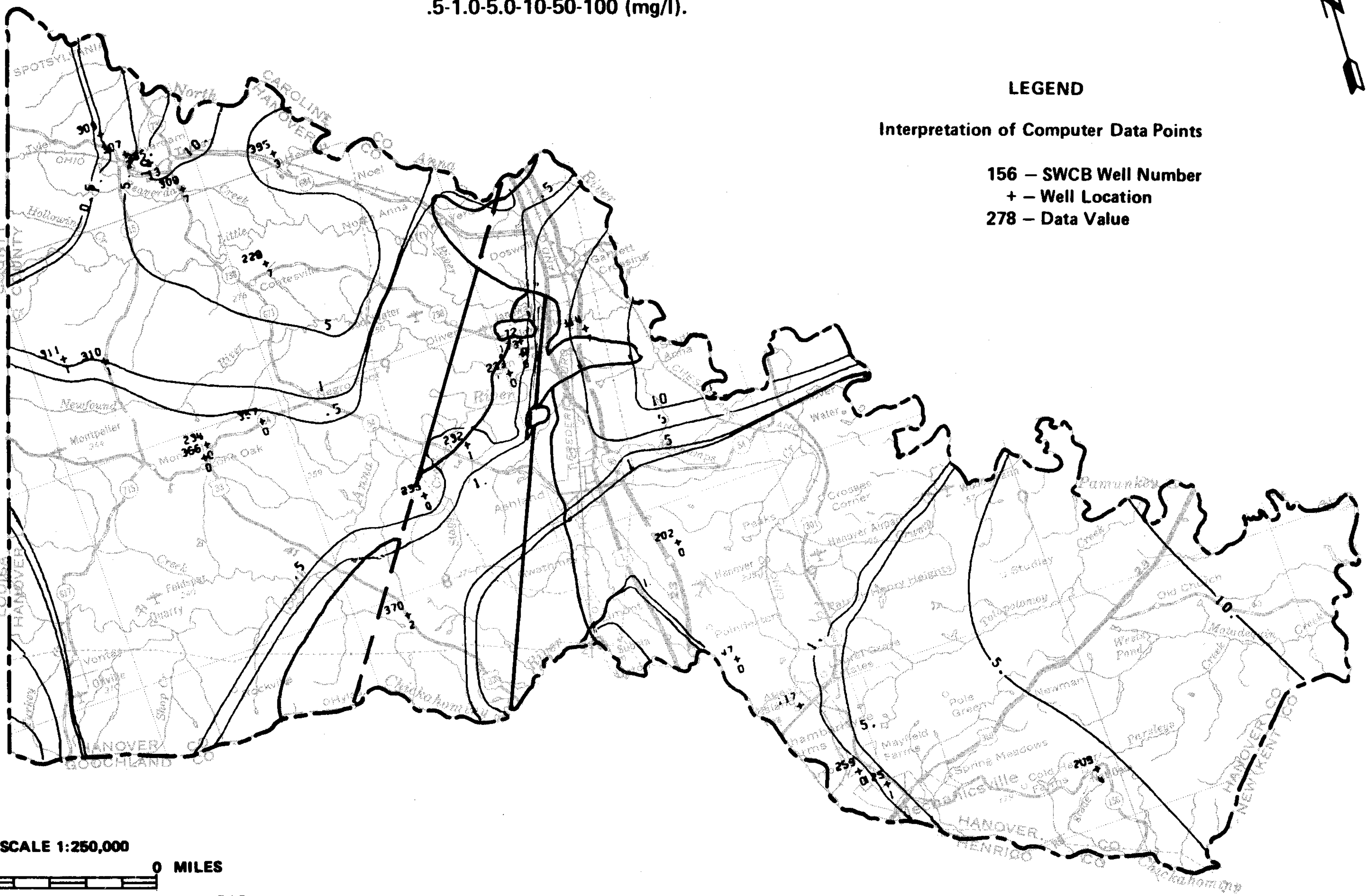
SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 34b. Contour map showing nitrate values for groundwater in the Piedmont and basement complex rocks. Contour intervals: .5-1.0-5.0-10-50-100 (mg/l).



LEGEND

Interpretation of Computer Data Points

156 – SWCB Well Number
+ – Well Location
278 – Data Value

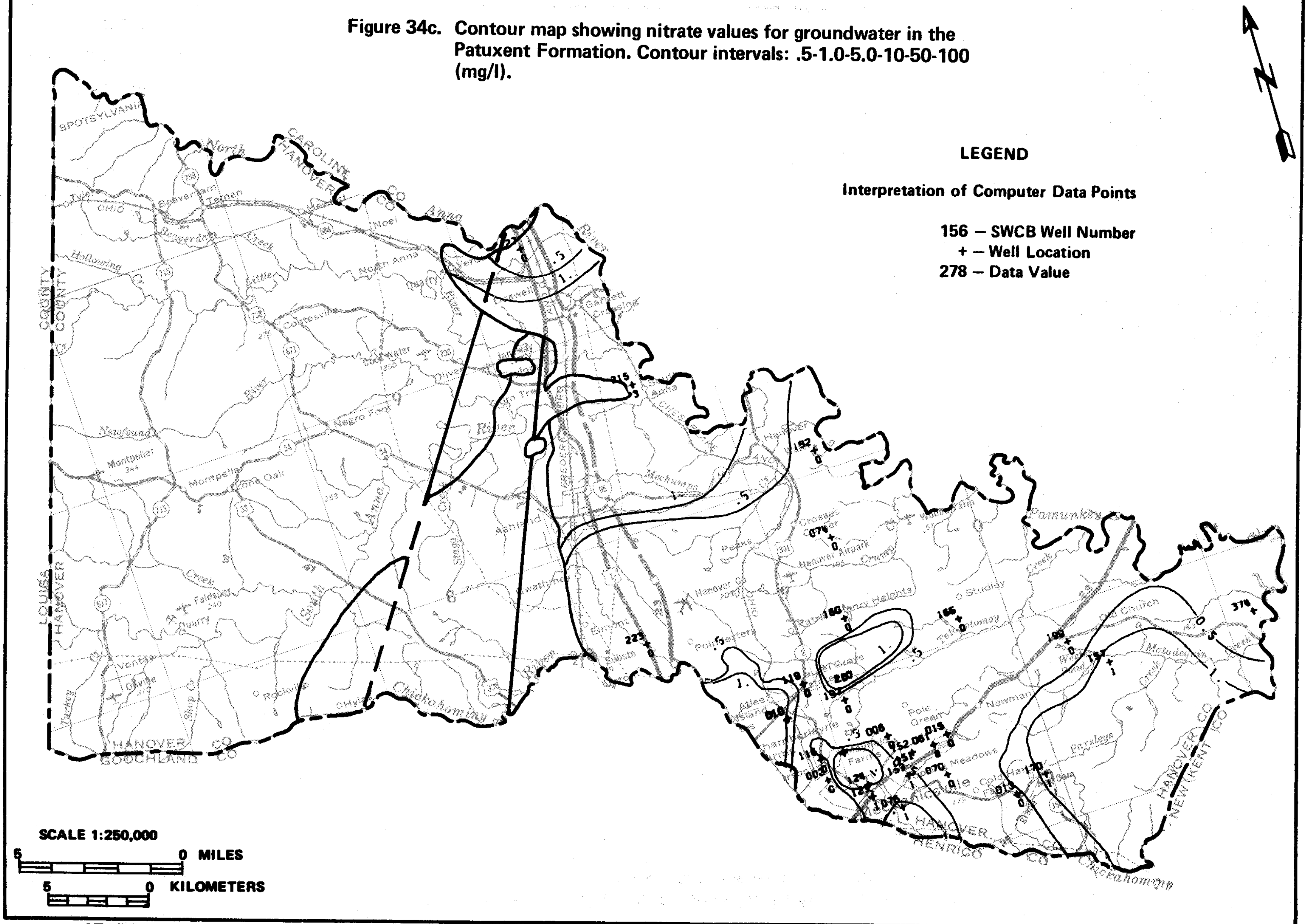
SCALE 1:250,000

5 0 MILES

5 0 KILOMETERS

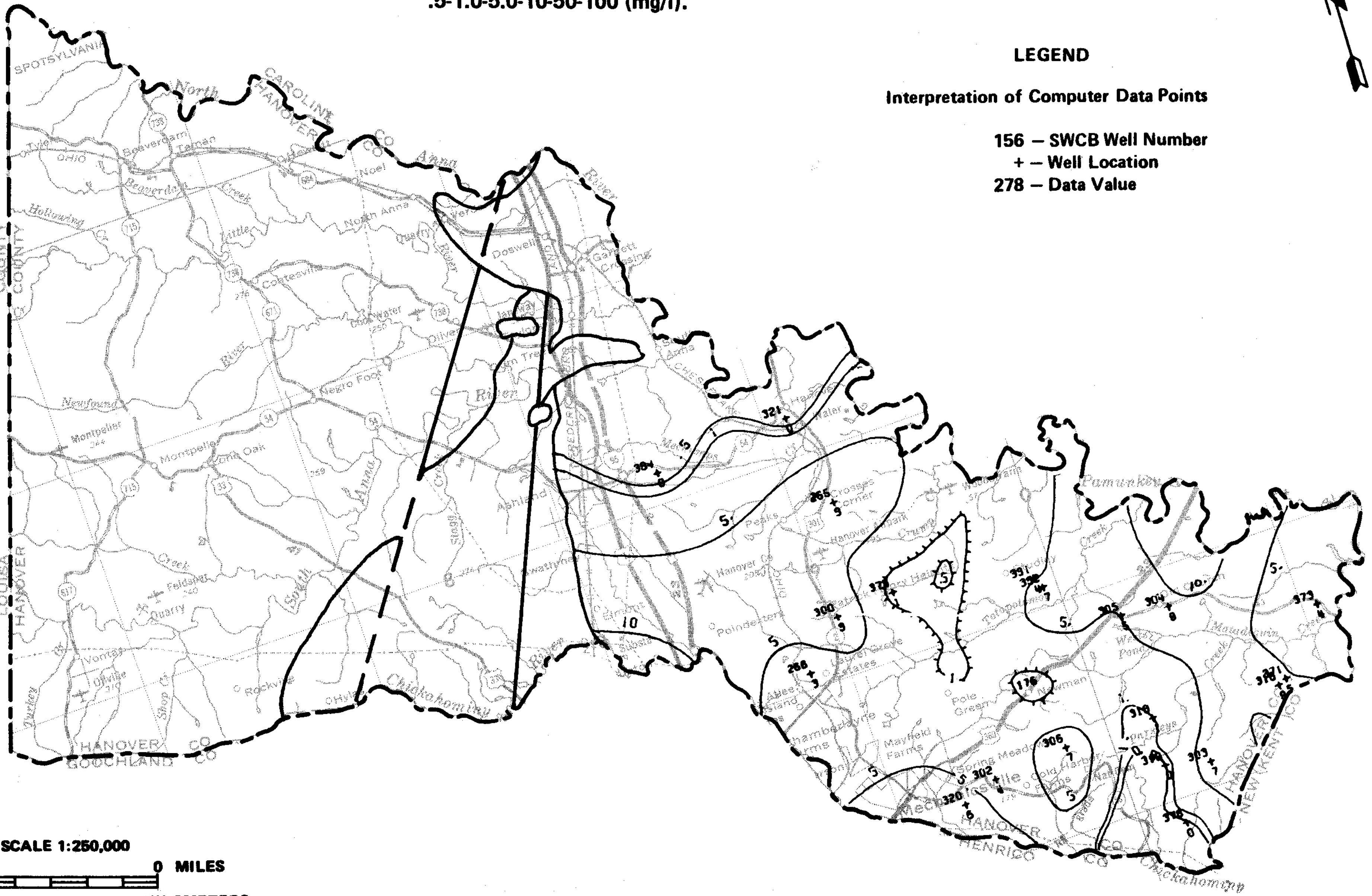
SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 34c. Contour map showing nitrate values for groundwater in the Patuxent Formation. Contour intervals: .5-1.0-5.0-10-50-100 (mg/l).



SOURCE: STATE WATER CONTROL BOARD – PRO, ADP.

Figure 34d. Contour map showing nitrate values for the Miocene clayey-silt and Tertiary-Quarternary sands and gravels. Contour interval: .5-1.0-5.0-10-50-100 (mg/l).



LEGEND

Interpretation of Computer Data Points

156 — SWCB Well Number
\+ — Well Location
278 — Data Value

SCALE 1:250,000

5 — 0 MILES

5 — 0 KILOMETERS

SOURCE: STATE WATER CONTROL BOARD — PRO, ADP.

CHAPTER VI

GROUNDWATER RECHARGE AND STORAGE

General

As partially discussed in the chapter on geohydrology, groundwater recharge is dependent upon precipitation, temperature, humidity, area of recharge, vegetation, topography, soils, rock type, and subsurface geology. Precipitation and its infiltration (which is dependent primarily upon the permeability and porosity of the geologic formation) are the most important factors affecting recharge. Generally, recharge rates are rapid in highly-fractured rocks and permeable sands and gravels, and very slow in unfractured rock and less-permeable clays and silts.

The groundwater-storage abilities of the aquifers in Hanover County vary greatly. Generally, aquifers of greater extent, thickness, permeability, and porosity have larger storage capacities than localized, less porous, thin aquifers.

porosity?

Piedmont

The saprolite cover has adequate permeability, but high intergranular friction, grain size variations, and van der Waal's forces impede groundwater infiltration. Because of this slow recharge rate, groundwater quality generally is improved after percolation through the saprolite.

Storage capacities of the saprolite are dependent upon the volume of interconnected saprolite cover. Deep saprolite covers can store large volumes of groundwater and, thus, can be very resistant to drought conditions.

The consolidated, Piedmont bedrock usually has either very rapid or very slow recharge rates. These rates are dependent upon the existence of fractures and joint networks within the crystalline rocks. A large volume of groundwater can pass through a fault zone and its interconnecting fractures with very little resistance from intergranular friction and van der Waal's forces that would be present in unconsolidated sediments.

Groundwater storage in the Piedmont bedrock is limited to the total volume of the interconnected fractures and joints. These features are usually of limited extent and can dry up completely in times of severe drought.

Coastal Plain

The surface-water tables in the Coastal Plain recharge rapidly as precipitation falls. But due to their thin, localized extent (small storage), they often go dry in times of drought. During droughts, groundwater quality can become poor due to ion concentration increases in the decreasing volume of water.

The artesian aquifers, both upper and principal, receive lateral recharge from the western outcrops of the formations themselves and vertical recharge from the highly porous (large storage), low permeability (low yield) clays of the upper, confining units. Lateral recharge is rapid once the groundwater has entered the highly-permeable artesian aquifer. Vertical recharge is very slow, but the large areal extent of the artesian aquifers enables vast amounts of groundwater recharge.

Artesian Aquifer Recharge (Patuxent Formation). The procedure used to determine the recharge of an artesian aquifer is complicated and many factors must be considered. A simplified explanation of this procedure for the Patuxent Formation (principal artesian aquifer) in Hanover County will be developed below.

As noted in previous chapters, infiltration of precipitation is the sole source of groundwater recharge. Total recharge into an artesian aquifer can be separated into its lateral and vertical components. Figure 35 shows the zones of lateral and vertical recharge in an artesian aquifer cross section.

Lateral recharge is supplied through the outcrop area of the formation. The Patuxent outcrop area equals 4.32 square miles or 1.2×10^8 square feet. Rainfall in this area averages 42 inches or 3.5 feet per year. It is estimated that 80% of the rainfall goes to runoff, vegetation, and evaporation, with 20% recharging the groundwater supply. Thus, 8.4×10^7 cubic feet or 6.3×10^8 gallons of water are available to infiltrate the outcrop area each year. A great portion of this water is available then to enter the confined portion of the aquifer (vertical recharge zone). The water constantly is migrating downdip into the confined portion of the aquifer. This migration (lateral recharge) and its rate are restricted by the volume of water already in the confined aquifer, the friction and physical forces associated with intergranular movements, and the thinnest section of aquifer through which the water must pass (Figure 7b).

The vertical recharge occurs over the confined surface area of the artesian aquifer. The extent of this surface for the Patuxent in Hanover County is 205.44 square miles. Rainfall in this area averages 43 inches or 3.58 feet per year. Again, it is estimated that runoff, vegetation, and evaporation take up 80% of the rainfall, with 20% remaining to infiltrate downward. Thus, 4.1×10^9 cubic feet or 3.06×10^{10} gallons of water are capable of percolating downward each year. However, the confining formations hinder the vertical infiltration because of intergranular friction and physical forces acting on the water in the clay layers. The tested hydraulic conductivity values for these confining layers are notably low (1-5 $gpd/ft^2/ft$) and the vertical recharge water finally enters the principal artesian aquifer at a yearly volume of less than 1% of the amount available for infiltration.

Artesian Aquifer Storage (Patuxent Formation). In order to estimate the total storage capacity of the principal artesian aquifer, it was necessary to interpret thickness data contained in Brown's report (1972) and shown in Figures 18b and 18c of this report. From these data, the volume of the Patuxent Formation was calculated to be 1.4×10^{12} cubic feet. It is estimated that 35% of the formation is pore space capable of containing water. Thus, total estimated groundwater storage of the Patuxent Formation in Hanover County is 4.9×10^{11} cubic feet or 3.67×10^{12} gallons of water. Since only 6% of this total volume is believed recoverable, total groundwater available from the confined Patuxent is 2.2×10^{11} gallons.

Conclusions

Storage values for the Piedmont section of the County are difficult to estimate. Any prediction for future availability and development in the Piedmont must be a tentative one at best.

The storage figures for the Patuxent indicate a vast supply of good quality groundwater available in the Coastal Plain portion of the County. There also exists a great potential for future development of the upper artesian system.

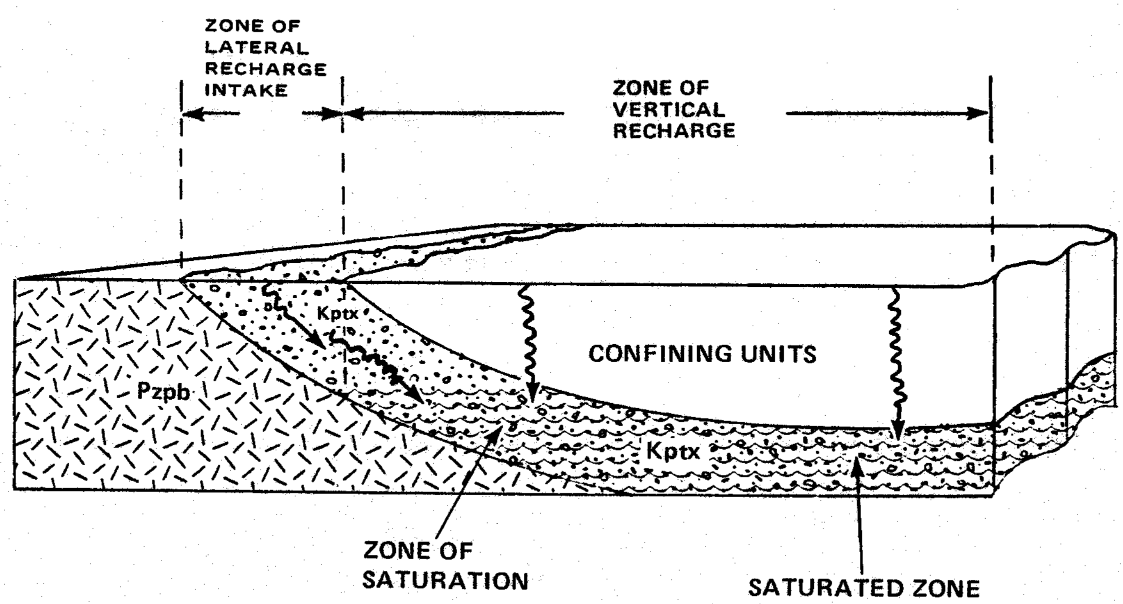


Figure 35. A schematic showing a subsurface cross-section of the Patuxent Formation and zones of lateral and vertical recharge.

SOURCE: STATE WATER CONTROL BOARD – PRO

CHAPTER VII

GROUNDWATER DEVELOPMENT

General

Any development of Hanover County's groundwater resource is limited by the groundwater availability, well construction and operation costs, and the water use. The availability of groundwater has been discussed in the geohydrology section of this report. The economics of well construction vary with well depth, geology, and location. The various groundwater uses dictate the yield and quality of water desired.

Well Construction and Cost (1978). Most shallow Piedmont wells tap the saprolite (less than 100 feet deep). They usually are bored wells of 30-inch diameter and cost from $6 to $8 a foot. Concrete casing and grout usually are required by county and state health regulations.

Deep wells in the Piedmont are usually six-inches in diameter and attempt to tap the bedrock fractures beneath the saprolite. The saprolite section of a deep well is usually steel cased and grouted. The hardrock portion must be drilled, commonly with an air hammer. No casing is used for the rock section of the well. Bedrock drilling costs range from $7 to $10 per foot, with an additional $5 to $7.50 per foot for casing and $300 total charge for grouting.

Shallow Coastal Plain wells are usually 30-inches in diameter, have a concrete casing with grouting, and cost approximately $6 to $8 per foot. A 400 foot-deep, six-inch steel cased, artesian well in the Coastal Plain, with 20 feet of screen and gravel pack, will cost approximately $10,000 to $12,000. These deep artesian wells are the largest and most dependable producers in the County.

Groundwater Use

Groundwater in Hanover County is used primarily for domestic, industrial, commercial, agricultural, and public supply purposes.

Domestic use includes both individual household wells and the public supply wells of the many subdivisions in the County (Figure 36).

Of 421 wells on record at the State Water Control Board, some 235 (55.8%) are individual household wells; 75 wells are public-supply-subdivision wells (17.8%). The gallon per day pumpage information for Hanover County subdivisions is listed in Table 12.

The industrial and commercial usage is unknown at this time due to the lack of complete information. The numbers of commercial and industrial wells reported to the State Water Control Board are 19 and 52, respectively. Major groundwater using industries in the County include Fiberlay Corporation, Fearnow Brothers Cannery, Feldspar Corporation, Richmond Food Stores, Southern Materials, Mobil Chemical, and Burroughs.

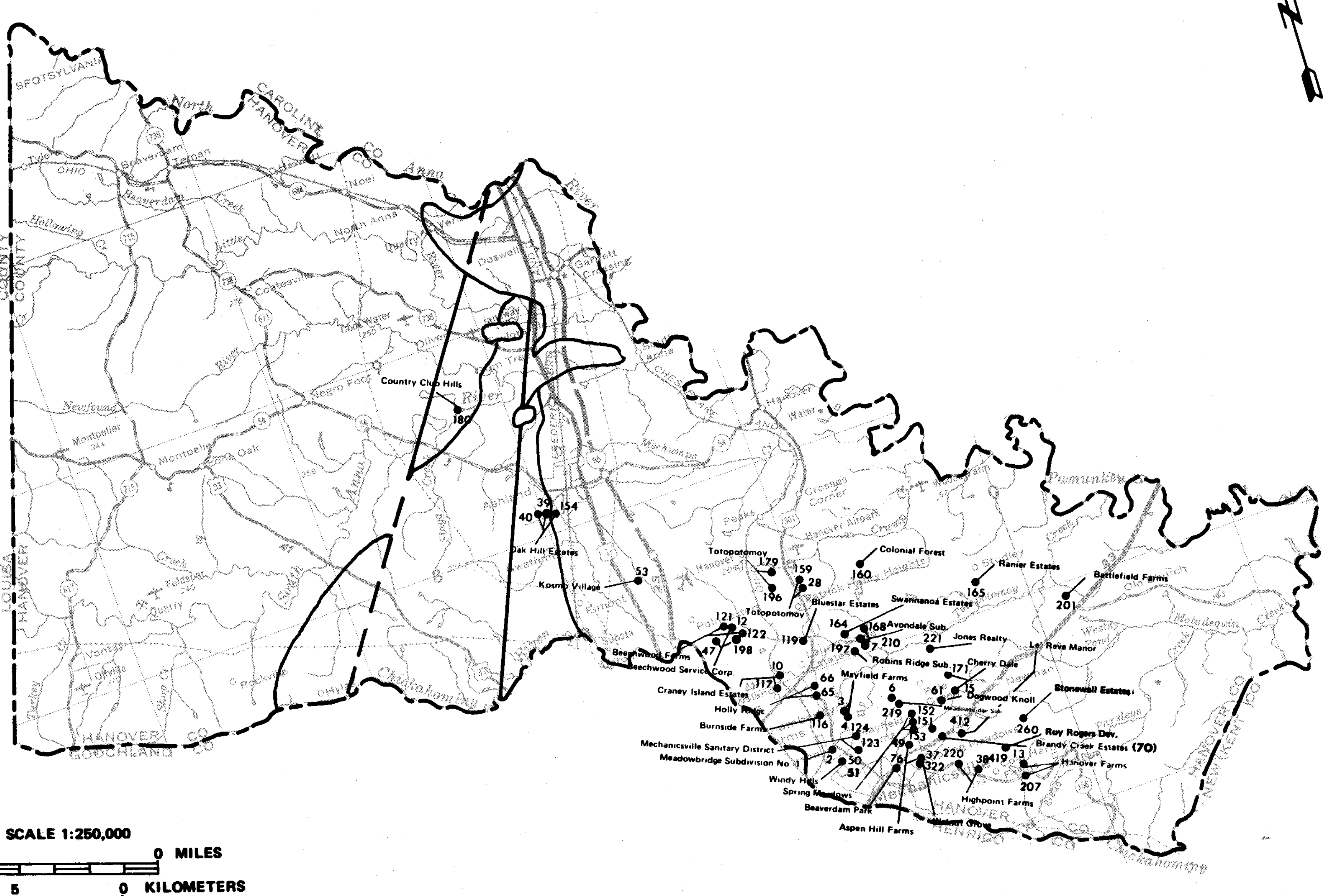
Public use wells include schools, public offices, and parks. These wells number 28 on record and are mostly associated with schools. A decade ago, the Town of Ashland abandoned its well system for a surface-water facility.

Total groundwater usage in Hanover County can best be estimated from population and housing information, excluding industrial, commercial, and agricultural use. The estimated population figure for 1978 is 60,000. The Town of Ashland has some 6,100 people who are using surface supplies and about 53,900 people using groundwater. If the estimate of 58 gallons per day of water use per person is accurate, then 3,126,200 GPD of groundwater are used. Computed another way, there are 15,900 single family houses in the County. If there are approximately 3.4 people per house and each person uses 58 gallons per day, then 3,135,480 GPD of groundwater are used. These figures indicate that approximately 1.14×10^9 gallons of groundwater are used in Hanover County each year.

TABLE 12

Name of Subdivision or Water System	SWCB Well Number	Pumpage (GPD) for 90 days (12-31-77 to 3-31-78)
Aspen Hills	142-49 (#1) 142-218 (#2)	23,811 no reading
Avondale	142-7 (#1) 142-210 (#2)	40,887 127,539
Brandywine	142-438	6,799
Diane Ridge	142-201	no reading
Georgetown	142-423	6,130
Hanover Heights	142-258	8,849
Highpoint Farms - Part #1 & #2	142-38 (#1) 142-220 (#2)	4,854 no reading
Holly Ridge	142-279	2,800
LeReve Manor	142-412	5,513
Mechanicsville Sanitary District		
Oak Avenue #3	142-125	54,239
Barnette Avenue #4	142-123 & 124	65,924
Arnoka Road #5	142-440	no reading
Battlefield Farms #6	142-200	35,339
Beaverdam Park #7	142-76	8,343
Oak Hill Estates #2	142-40	2,853
#4	142-154	no pumpage
#5	142-261	3,193
Sinclair Manor #1	142-225	55.5
Stonewall Estates #1	142-260	11,005
Strawhorne #1	142-221	10,560
Totopotomoy #2	142-196	58,880
Walnut Grove #1	142-227	9,163
		486,736.5

Figure 36. Map showing subdivisions using groundwater well systems.



SOURCE:

APPENDIX I

Form GW-2
1978-10,000

COMMONWEALTH OF VIRGINIA

WATER WELL COMPLETION REPORT

● BWCM No. ______

(Certification of Completion/County Permit)

State Water Control Board
P. O. Box 11143
2111 North Hamilton St.
Richmond, Va. 23230

SWCB Permit ______
County Permit ______

Certification of inspecting official:
This well does ______ does not ______
meet code/low requirements.
S. ______
Date ______

For Office Use

County/City Stamp

● Virginia Plane Coordinates
______ N
______ E
Latitude & Longitude
______ N
______ W
● Topo. Map No. ______
● Elevation ______ ft.
● Formation ______
● Lithology ______
● River Basin ______
● Province ______
● Type Logs ______
● Cuttings ______
● Water Analysis ______
● Aquifer Test ______

● Owner ______
● Well Designation or Number ______
Address ______
Phone ______

● Drilling Contractor ______
Address ______
Phone ______

Tax Map I.D. No. ______
Subdivision ______
Section ______
Block ______
Lot ______
Class Well: I ______, IIA ______,
IIB ______, IIIA ______, IIIB ______

WELL LOCATION: ______ (feet/miles ______ direction) of ______
and ______ feet/miles ______ (direction) of ______
(If possible please include map showing location marked)

Date started ______ ● Date completed ______ Type rig ______

1. WELL DATA:
New ______ Reworked ______ Deepened ______
● Total depth ______ ft.
● Depth to bedrock ______ ft.
● Hole size (Also include reamed zones)
● ______ inches from ______ to ______ ft.
● ______ inches from ______ to ______ ft.
● ______ inches from ______ to ______ ft.
● Casing size (I.D.) and material
● ______ inches from ______ to ______ ft.
Material ______
Wt. per foot ______ or wall thickness ______ in.
● ______ inches from ______ to ______ ft.
Material ______
Wt. per foot ______ or wall thickness ______ in.
● ______ inches from ______ to ______ ft.
Material ______
Wt. per foot ______ or wall thickness ______ in.
● Screen size and mesh for each zone (where applicable)
● ______ inches from ______ to ______ ft.
● Mesh size ______ Type ______
● ______ inches from ______ to ______ ft.
● Mesh size ______ Type ______
● ______ inches from ______ to ______ ft.
● Mesh size ______ Type ______
● ______ inches from ______ to ______ ft.
● Mesh size ______ Type ______
● Gravel pack
● From ______ to ______ ft.
● From ______ to ______ ft.
● Grout
● From ______ to ______ ft., Type ______
● From ______ to ______ ft., Type ______

2. WATER DATA
● Water temperature ______ °F
● Static water level (unpumped level-measured) ______ ft.
● Stabilized measured pumping water level ______ ft.
● Stabilized yield ______ gpm after ______ hours
Natural Flow: Yes ______ No ______, flow rate: ______ gpm
Comment on quality ______

3. WATER ZONES:
From ______ To ______
From ______ To ______. From ______ To ______
From ______ To ______. From ______ To ______

4. USE DATA:
Type of use: Drinking ______, Livestock Watering ______,
Irrigation ______ Food processing ______, Household ______,
Manufacturing ______, Fire safety ______, Cleaning ______,
Recreation ______, Aesthetic ______, Cooling or heating ______,
Injection ______, Other ______
● Type of facility: Domestic ______, Public water supply ______,
Public institution ______, Farm ______, Industry ______,
Commercial ______, Other ______

5. PUMP DATA:
Type ______ ● Rated H.P. ______,
● Intake depth ______ ● Capacity ______ at ______ head

6. WELLHEAD:
Type well seal ______
Pressure tank ______ gal., Loc. ______
Sample tap ______, Measurement port ______
Well vent ______, Pressure relief valve ______
Gate valve ______, Check valve (when required) ______
Electrical disconnect switch on power supply ______

7. DISINFECTION:
Well disinfected ______ yes ______ no
Date ______, Disinfectant used ______
Amount ______, Hours used ______

8. ABANDONMENT (where applicable)
● yes ______ no ______
Casing pulled yes ______ no ______ not applicable ______
Plugging grout From ______ to ______ material ______

Owner ______________________ BWCM No.__________

9. State law requires submitting to the Virginia State Water Control Board information about groundwater and wells for every well made in the State intended for water, or any other non-exempt well. This information must be submitted whether the well is completed, on standby, or abandoned. Information required includes: an accurately and completely prepared water well completion report, full data from any aquifer pumping tests, drill cuttings taken at ten foot intervals (unless exemption is secured), the results of any chemical analyses, and copies of any geophysical logs. Quarterly pumpage and use reports are required from owners of public supply and industrial wells. County or State permits to drill may be required in some parts of the state. Some counties require submission of a water well completion report. The Virginia State Health Department requires a water well completion report for public supply wells.

10. DRILLERS LOG (use additional Sheets if necessary)				11.	12. DIAGRAM OF WELL CONSTRUCTION (with dimensions)
DEPTH (feet)		TYPE OF ROCK OR SOIL	REMARKS	Drilling Time (Min.)	
From	To	(color, material, fossils, hardness, etc.)	(water, caving, cavities, broken, core, shot, (etc.)		

State Water Control Board Regional Offices

Valley Reg. Off.
116 North Main Street
P. O. Box 268
Bridgewater, Va. 22812
703-828-2595

Piedmont Reg. Off.
4010 West Broad Street
P. O. Box 6616
Richmond, Va. 23230
804-257-1006

Southwest Reg. Off.
408 East Main Street
P. O. Box 476
Abingdon, Va. 24210
703-628-5183

Tidewater Reg. Off.
287 Pembroke Office Park
Suite 310 Pembroke No. 2
Va. Beach, Va. 23462
804-499-8742

West Central Reg. Off.
Executive Park
5306 A Peters Creek Road
Roanoke, Va. 24019
703-563-0354

Northern Virginia Reg. Off.
5515 Cherokee Avenue
Suite 404
Alexandria, Va. 22312
703-750-9111

13. Well lot dedicated? ______; Size ______ ft. X ______ ft.; Well house? __________
Distance to nearest pollutant source __________ ft., Type __________
Distance to nearest property line __________ ft., Building __________ ft.

14. I certify that the information contained herein is true and correct and that this well and/or system has been installed and constructed in accordance with the requirements for well construction as specified in compliance with appropriate county or independent city ordinances and the laws and rules of the Commonwealth of Virginia.

Signature ______________________________(Seal), Date ______________
(Well driller or authorized person)
License No. ______________________

FORM GW-5
8/74 1000

COMMONWEALTH OF VIRGINIA
STATE WATER CONTROL BOARD
P. O. Box 11143, 2111 North Hamilton Street
Richmond, Virginia 23230
Phone (804) 770-1411

APPLICATION AND REPORT
ABANDONMENT OF WATER WELL
(For use in all groundwater areas)

(Card 28)

I. APPLICATION

OWNER: ______________________________
1-20

ADDRESS: ______________________________
____
21-60

WELL LOCATION: ______________________________

Owner herewith applies to abandon (check which) temporarily ( )61 or permanently ( )62 his water well identified by:

1. Application and Permit to Construct a Water Well number __________,
63-66

2. Certificate of Groundwater Right number __________.
67-70

If (1) and (2) above are not applicable, complete the following statement:

MAXIMUM DAILY WITHDRAWAL OF GROUNDWATER IS __________ GALLONS.
71-78

(Card 29)

USE TO WHICH GROUNDWATER WAS APPLIED: ______________________________.

TOTAL DEPTH OF WELL: __________ FEET.
1-4

EXACT DATE ON WHICH ABANDONMENT WILL BE DONE: __________.
5-10

NOTE: 1. Applicant shall furnish a sketch of water well and indicate proposed procedures and materials to be used in abandonment.

2. Abandonment shall conform with IIIF, "Standards for Water Wells", published by the Board.

APPLICATION APPROVED BY: ______________________________
11-40

DATE: ______________________________
41-46

(Card 30)

II. REPORT

Owner certifies that abandonment was in accordance with "Standards for Water Wells" and any further specifications of the Board.

Water well removed from service temporarily ( )[1] or permanently ( )[2] on ____________________ (date).
3-8

SIGNATURE: ______________________________
9-30

DATE: ______________________________
31-36

INSPECTION OF ABANDONMENT (Card 31)

INSPECTED BY: ________________________. TITLE: ______________________.
1-15 16-25

DATE OF INSPECTION: ____________________.
26-31

COMMENTS: ____

____

____

COPY SENT TO DEPARTMENT OF HEALTH BY: ________________________________
32-50

DATE: ________________________________
51-56

FORM GW-6
12/75 5,000

COMMONWEALTH OF VIRGINIA
STATE WATER CONTROL BOARD

P. O. Box 11143, Richmond, Virginia 23230
Phone (804) 786-1411

QUARTER OF YEAR

1 2 3 4

(Circle One)

GROUNDWATER PUMPAGE AND USE REPORT

-Required Quarterly-
(For use in all groundwater areas)

I. GENERAL:

a. OWNER OF WELL/SYSTEM: ______
ADDRESS: ______ PHONE: ______

b. NAME OF WELL/SYSTEM: ______

c. LOCATION OF WELL/SYSTEM: ______ COUNTY/CITY

II. WELL DATA:

This form submitted for (a) _____ an individual water well, or (b) ____ a system of water wells (list water well(s) below: TOTAL OR ESTIMATED PUMPAGE below is pumpage for that water well or that system only).

OWNER'S WELL IDENTIFICATION	SWCB WELL NUMBER	PUMPING LEVEL	STATIC WATER LEVEL	TOTAL DEPTH OF WELL	DATE OF CONSTRUCTION

III. SYSTEM AND PUMPAGE INFORMATION

a. ( ) PUBLIC WELL/SYSTEM, SERVING ______ CONNECTIONS, OR
b. ( ) INDUSTRIAL WELL SYSTEM
WATER APPLIED TO WHAT USE ______

PREVIOUS METER READING: ______ DATE: ______
CURRENT METER READING: ______ DATE: ______

TOTAL PUMPAGE ______ GALLONS. AVERAGE PUMPAGE ______ GALLONS PER DAY

or ______ GALLONS PER MINUTE

Note: To obtain average pumpage, divide total gallons by number of pumping days or minutes.

IF WELL/SYSTEM IS NOT METERED, ESTIMATED AVERAGE PUMPAGE IS ______ GPD.

Note: Estimated pumpage for public system = connections x 320 gpd.

THIS REPORT COVERS THE PERIOD FROM ______ TO ______
(date) (date)

DATE SUBMITTED ______ I-6 SIGNATURE: ______

APPENDIX II

****

THE FOLLOWING LIST OF WELL DATA SUMMARIZES BASIC DATA OBTAINED FROM WATER WELL COMPLETION REPORTS WHICH ARE ON PERMANENT FILE IN THE OFFICES OF THE VIRGINIA STATE WATER CONTROL BOARD. ADDITIONAL INFORMATION FOR MANY OF THE WELLS IS AVAILABLE AND CAN BE OBTAINED BY CONTACTING THE APPROPRIATE REGIONAL OFFICE OR THE BUREAU OF WATER CONTROL MANAGEMENT AT THE AGENCY HEADQUARTERS IN RICHMOND.

************ EXPLANATION OF PARAMETERS ************

SWCB NO: STATE WATER CONTROL BOARD NUMBER - A SEQUENTIAL NUMBERING SYSTEM USED WITHIN A COUNTY; WHEN REFERRING TO A SPECIFIC WELL USE THIS NUMBER

OWNER AND/OR PLACE: IDENTIFIES ORIGINAL OR CURRENT WELL OWNER AND/OR LOCATION OF WELL

YEAR COMP: YEAR IN WHICH WELL CONSTRUCTION WAS COMPLETED

LOG: TYPE OF LOG ON FILE FOR WELL; D = DRILLERS, E = ELECTRIC, G = GEOLOGIC

ELEV: ELEVATION - MEASURED IN FEET ABOVE MEAN SEA LEVEL

TOTAL DEPTH: TOTAL DEPTH DRILLED, IN FEET, WITH RESPECT TO LAND SURFACE

BEDROCK: DEPTH TO BEDROCK, IN FEET, WITH RESPECT TO LAND SURFACE

CASING: MAXIMUM AND MINIMUM DIAMETER OF CASING, IN INCHES, USED IN WELL

DEVEL ZONE: DEVELOPED ZONE - INTERVALS, IN FEET, WHERE AQUIFERS TAPPED AND/OR SCREENED

AQUIFER: WATER-BEARING UNIT; ABBREVIATIONS USED INDICATE GEOLOGIC AGE OF UNIT AND ARE CONSISTENT WITH "GEOLOGIC MAP OF VIRGINIA" (DIVISION OF MINERAL RESOURCES - 1963)

STATIC LEVEL: DEPTH, IN FEET, TO WATER WITH RESPECT TO LAND SURFACE; MEASUREMENTS TAKEN WHEN WELL IS NOT PUMPED AND ARE GENERALLY THOSE RECORDED ON COMPLETION DATE

YIELD: REPORTED OR MEASURED PRODUCTION, IN GALLONS PER MINUTE

DRAWDOWN: DIFFERENCE, IN FEET, BETWEEN STATIC LEVEL AND PUMPING LEVEL; I.E., REPORTED OR MEASURED DROP, IN FEET, IN WATER LEVEL DUE TO PUMPING

SPEC CAPAC: SPECIFIC CAPACITY - YIELD PER UNIT OF DRAWDOWN EXPRESSED AS GALLONS PER MINUTE PER FOOT OF DRAWDOWN

HRS: HOURS - DURATION OF PUMP TEST, IN HOURS, FROM WHICH THE PRECEDING THREE ITEMS WERE DERIVED

USE: USE OF WATER OR WELL UNDER CONSIDERATION; DOM = DOMESTIC, PUB = PUBLIC, GOV = GOVERNMENT, IND = INDUSTRIAL, COM = COMMERCIAL, INS = INSTITUTIONAL, ABD = ABANDONED, DST = DESTROYED, IRR = IRRIGATION, RCH = ARTIFICIAL RECHARGE

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

DATE 11/28/78

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
1	R W STARKE	67		145	300		5	4	220	261		129	17	79	.21		DOM
2	E G WADE	68	D	140	600	205	6		184	209		177	70	42	1.66	8	PUB
	MEADOWBRIDGE SUB#1																
3	SYDNOR MAYFIELD FARMS	62	D	190	278		6		217	227		149	82	98	.83	24	PUB
4	SYDNOR,MAYFIELD FARMS	58	E		316		6										PUB
5	COLD HARBOR VISIT CEN	62	DE	175	280		6	4	255	270		135	20	75	.26	7	PUB
6	SYDNOR MEADOWGATE SUB	67	D	175	306		6		198	218		157	30	74	.40	6	PUB
7	SYDNOR, AVONDALE SUB	66	DE	185	370		6	4	238	248		143	178	67	2.65	5	PUB
8	RICHMOND FOOD STORES	67	DE	185	275	265	6		164	174		125	31	55	.56	8	COM
9	RICHMOND FOOD STORES	67	D	140	708	250	6					135	21	160	.13	4	COM
10	HANOVER WATER CO	65	DEG	200	395	287	6		186	216		157	21	83	.25	5	PUB
	CRANEY ISLAND ESTA																
11	SUNNOCO OIL CO.	70	D	175	245		4					149	12	55	.21		COM
12	BEECHWOOD SER CORP	67	D	185	640		6	4	118	123		110	14	190	.07	8	PUB
									130	135							
13	SYDNOR HANOVER FARMS	64	D	150	401		6	4	233	253		135	85	69	1.23	7	PUB
14	H S SPENCER #2	65	D	145	444		4		303	313		144	20	36	.55		INS
15	SYDNOR CHERRYDALE	68	D	170	412		6		320	370		140	120	60	2.00	6	PUB
16	MOBIL CHEMICAL CO.	67	D	190	322	87	7				PZPB		1				ABD
17	MOBIL CHEMICAL CO	64	D	175	145		6					49	100	96	1.04	2	COM
18	MOBIL CHEMICAL	67	D	150	200	50	7				PZPB	31	280	45	6.22	9	IND
19	SIGNAL HILL MEM PARK	68	D	180	266		6		246	266		125	113	70	1.61	14	COM
20	BURROUGHS	66	D	170	200	31	5				TRNS	60	5				DOM
21	VIRGINIA M MCCRACKEN	65	D	195	120	48	5				TRNS	45	30	45	.66		DOM
22	R W HERZOG	67	D	285	255	10	5		220	221	GRGN	20	10	218	.04		DOM
23	LOUIS B MORRIS	55		180	313		6					34	1	279			DOM
24	J H COCHRAME	62	D	175	146	50	6				GRGN	6	10			2	DOM
25	JOHN WORKMAN	64	D	185	142	45	5					36	10				DOM
26	E I PEET	65	D	125	100	37	5				PZPB	10	20				DOM
27	R G CARLTON, JR	66	D	200	110	5	5						20				DOM
28	TOTOPOTOMOY INC.	68		190	300		6						48	74	.64	24	PUB
29	HANOVER COUNTRY CLUB		E	210	624							51					COM
30	BENJAMIN W HUTCHESON	64	D	200	107	32	6				PZPB	30	40				DOM
31	M L LOWRY	63	D	270	200	18	5				GRGN	18	1				ABD
32	AUTHOR FLIPPO	57	D	155	250	100	6				PZPB						ABD
33	ARTHUR P FLIFPO	65	D	200	280	70	5				PZPB	20	3	260	.01		ABD
34	J H KING	22	D	245	156							21	40			1	DOM
35	SCOTCHTOWN			285	207							50	1				PUB
36	DAVID G HARRISON	67	D	185	85	15	6					23	20				DOM
37	SYDNOR, WALNUT GROVE	69	D	130	304		6		264	289			42	72	.58	7	PUB
38	SYDNOR HIGH POINT FAR	69	D	180	370		4	5	279	285		171	79	31	2.54	7	PUB
39	LEROY BOSHEN OAK HILL	62	D	245	240							18	6				PUB
40	LEROY ROSHEN		D	260	240	59	6				TRNS	18					PUB
	OAK HILL																

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
41	D C LADE	68	D	185	147	44	6					32	5	107	.04		DOM
42	G R DAVIS				97							24	30				DOM
	BENT BROOK POULTRY																
43	KENNITH C MOORE	67	D	225	165	10					TRNS		10				DOM
44	SHADY GROVE MOTEL	62	D	220	395	78	6				TRNS	34	3			1	COM
45	H E SHAMBURGER	67	D	95	150	41	6						12				DOM
46	A A WALSH	65	D	195	155	90	5				PZPB		20			1	DOM
47	BEECHWOOD SERV CORP	69	D	110	310	80	6				PZPB	21	61	110	.55	10	PUB
	BEECHWOOD FARMS PWZ																
48	J N THOMASSON	62	D	185	145	29	6				TRNS		4			1	DOM
49	ASPEN HILL FARMS JETE	72	D	170	330		6		307	327		175	120	73	1.64	73	PUB
50	HANOVER COUNTY	61	DE	180	276	267	6		200	210		195	5				ABD
	WINDY HILLS																
51	HANOVER COUNTY	62	DE	180	608	267			200	210		164	104			24	PUB
	WINDY HILLS																
52	A W HARGROVE	66	D	200	160	36	5						20				DOM
53	KOSMO VILLAGE SHOOK	66	D	195	250		7					63	53				DOM
54	HANOVER REALTY CORP.	74	D		302		6		228	258		170	43	10	4.30	24	PUB
	R T HOLLY																
55	H N PERKINS			180													PUB
56	SPEED AND BRISCOE	66	D	205	350	104	6				PZPB	21	6	234	.02	13	COM
57	SPEED & BRISCOE	66	D	205	500	101	6				PZPB	16	2	326		7	COM
58	SPEED & BRISCOE	66	D	205	295	91	6				PZPB	15	3				PUB
59	VCU-MCV ANIMAL RESEAR	69	D	202	282	105	6				PZPB	31	18	169	.10	36	INS
60	MITCHELLS WELL & PUMP	62		175	320		6		305	315		142					PUB
	DOGWOOD KNOLL																
61	MITCHELLS WELL & PUMP	62	D	180	320		6		305	315		142	75	126	.59	75	PUB
	DOGWOOD KNOLL #2																
62	TOWN OF ASHLAND	07	D	210	221	54	10					. 8	55				ABD
63	TOWN OF ASHLAND	07	D	210	364	51	10						25				ABD
64	TOWN OF ASHLAND		D	210	754	42							40			1	ABD
65	SYDNOR HOLLY RIDGE #2	67	D	200	274		6					165	48	208	.23	6	PUB
66	SYDNOR, HOLLY RIDGE	67	DE	205	632	324	6					175	50			5	PUB
67	PIG PARLOWS WATER SUP	67	D		302				277	297							PUB
68	S D FLEET	65	E		369		6	4	292	332		19	60	46	1.30	16	DOM
69	T.D. LEADBETTER	68		205	196		6					26	175	196	.89	36	COM
70	BRANDY CREEK ESTATE	69	D	170	325		6		305	325		165	102	80	1.27	28	PUB
71	MITCHELLS WELL & PUMP	62	D	160													PUB
	BRANDY CREEK ESTATE																
72	NAT PARK SERV	61	D	150	199		4		181	191			5				GOV
73	HANOVER COUNTY	61	D		301		6		227	247		167	70	58	1.20	12	PUB
	RIDGEVIEW ESTATES																
74	JANIE P BARRETT SCH#2	49	D	125	277		8		249	265		134	46	16	2.87	24	INS
75	N KIRBY	55	D		326	324	6		234	249		113	132	104	1.26		DOM

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

DATE 11/28/78

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
76	BEAVERDAM PARK	72		150	320				277	318		162					DOM
77	T W JONES		D		150	26	6						4			2	DOM
78	S H LUNDH	44	D		265	96	6					23	4	217	.01	20	DOM
79	SOUTHERN MATERIALS	59	D		155	28	6					16	60	139	.43	3	IND
80	BARKSDALE THEATRE		E	80	234							65					COM
81	WALTER F PAYNE	59	D		197		4					117	13	19	.68	8	DOM
82	S W RIDDELL	64	D	247	320	60	6				TRNS	57	7				DOM
83	C E ODELL	64	D	210	140	90	6				TRNS	51					DOM
84	SUMMERVILLE	29			108		8					28	82	72	1.13	24	DOM
85	J L STINSON	65	D		185	50	5				GRGN		30				DOM
86	EDWARD C STEVENS	66	D		300	55	5					50	5				DOM
87	THROCKMORTON PROPERTY	67	D		195	15	5					30	12	155	.07		DOM
88	LINWOOD E. TOOMBS	65	D	178	173	25	7				PZPB	8	150				PUB
89	RICHMOND BATTLE PARK	65		180	196		4										GOV
90	RAINBOW LAKE MOTEL	55	D		290	45	6					33	4	186	.02	7	COM
91	JOHN C TYREE	40	D		129	87	6				PZPB	42	10	67	.14	9	DOM
92	HANOVER WAYSIDE PARK			160													DOM
93	VA. SPRINKLER CO.	62	D	155	100		5					15	6	63	.09	2	COM
94	E C C WOODS	55		100	120		4										DOM
95	R J WILSON	53	D		123	97	6	5				10	18	60	.30		DOM
96	J H COCHRANE	54	D		152	86	8				GRGN	20	25	114	.21	4	DOM
97	L.M. CARTER	67		200	345	10	5					20	1				ABD
98	DANIEL CONSTRUCTION	67	D	150	221	16	6					5	10	18	.55		ABD
99	J H COCHRANE	53	D		203	52	6				GRGN	46	48	37	1.29	6	DOM
100	NEAR ROCKVILLE	53	D		79	24	6				GRGN	17	1	58	.01		DOM
101	J E JONES	43	D		160	113	6					12	22	97	.22	9	DOM
102	JOHN W. HARGROVE	61		190	150	24	6				PZPB	29	17	1	17.00		DOM
103	JOHN W. HARGROVE	61	D	190	30	24	9										DOM
				85	200							52			.38		
104	LEE-DAVIS HIGH SCHOOL	69	D	155	286		6		265	285		140	50	24	2.08	12	INS
105	LOGAN DYKE	62	D	305	400	48	6				PZPB	25	1				ABD
106	FIBERLAY INC	55	D	120	200	25	6					20	75	33	2.27	18	COM
107	R G CARLTON JR	66	D		120	22	5				TRNS		10				DOM
108	E GRAY BOWLES	52	D		212	2	6					1	66	84	.78	8	DOM
109	ARTHUR P FLIPPO	65	D		280		5		19	29			3				DOM
110	C F CROSS	62	D		118	41	5						5				DOM
111	D D EANIS	49	D		151	67	6				PZPB	21	17	107	.15	8	DOM
112	T M FRAZIER	43	D		167	33	6				PZPB	30	31	64	.48	5	DOM
113	JOHN GIRAGOSIAN	54	D		344	15	6				PZPB						ABD
114	FRANK D HARGROVE	63	D		282	20						47					DOM
115	FRANK D HARGROVE	63	D		200	28	5					15					DOM
116	SYDNOR,BURNSIDE FARMS	57	E	175	270	265	5		174	189							PUB
117	CRANEY ISLAND ESTATES	58		170	305		6					128	50	112	.44		PUB
118	B.P. OIL CORPORATION	72	D	150	350	50	6										PUB

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
119	BLUE STAR ESTATES	65	DE	180	355		6		230	260			100	36	2.77	24	PUB
	BLUE STAR ESTATES																
				180	600		6		230	260		150			.35	24	
									200	300							
120	HOLLY FARMS POULTRY	66	D		306		6					9	2				IND
121	BEECHWOOD SERV CORP	69	D	150	653	165	6		167	187			3	490			PUB
	BEECHWOOD FARMS																
122	BEECHWOOD SERV CORP			180	136	132	4		76	96		78	2				DST
	BEECHWOOD FARMS																
123	MECHANICSVILLE SAN DI			195	261		10										PUB
124	MECHANICSVILLE SAN DI			165	225		8		195	220							PUB
125	MECHANICSVILLE SAN DI			195	498		6										PUB
126	1ST BAPTIST BENE ASSO		E	165	298				182	197							INS
127	EVANS PRODUCTS CO	69	D	130	312		6					27	50	33	1.51	10	COM
128	EVANS PRODUCTS CO	69	D	130	250	34	6				TRNS	18	7				IND
129	EVANS PRODUCTS INC	69	D	70	145	50	6				TRNS	32	118	28	4.21	10	IND
130	EVANS PRODUCTS INC	69	D	130	160	5	7				TRNS	32	30	51	.58	3	IND
131	EVANS PRODUCTS INC	70	D	70	175	20					TRNS	21	165	80	2.06	12	IND
132	HOLLY FARMS POULTRY			250									50				IND
133	HOLLY FARMS POULTRY			250									13				IND
134	HOLLY FARMS POULTRY			250									12				IND
135	HOLLY FARMS POULTRY			250									10				IND
136	HOLLY FARMS POULTRY			250									3				IND
137	HOLLY FARMS POULTRY			250									4				IND
138	HOLLY FARMS POULTRY			250									11				IND
139	HOLLY FARMS POULTRY			250									4				IND
140	HOLLY FARMS POULTRY			250									2				IND
141	HOLLY FARMS POULTRY			250									2				IND
142	HOLLY FARMS POULTRY			250									5				IND
143	HOLLY FARMS POULTRY			250									5				IND
144	HOLLY FARMS POULTRY			250									10				IND
145	V E PORTWOOD	50	D	175	356		4					130	6	38	.15	5	DOM
146	VA DEPT OF HIGHWAYS	50	D	220	412	92	6					12	1	238			DOM
147	LEADBETTER CONST. CO.	70	D	205	250	69	6				PZPB		2				DST
148	LEADBETTER CONST. CO.	70	D	205	250	66	8	6			PZPB		5				DST
149	LEADBETTER CONST. CO.	70	D	200	250	60					PZPB		2				DST
151	SYDNOR HYDRODYNAMICS	58	E	165	350	350							175	115	1.52		PUB
	SPRING MEADOWS																
152	SYDNOR PUMP & WELL #2	60		160	308		6		270	305		121	183				PUB
	SPRING MEADOWS																
153	SYDNOR HYDRODYNAMICS	65	D	165	320		8		258	278		139	115	114	1.00	8	PUB
	SPRING MEADOWS																
154	OAK HILL WATER CO	68	D	250	325	71	6				TRNS	20	12	250	.04	24	PUB
	OAK HILL ESTATES																

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT — DATE 11/28/78

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY —

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
155	OVERHILL FARMS WTR CO				38	38	30										PUB
156	OVERHILL FARMS WTR CO	62			36		30										PUB
157	MATTAQUIN CORP		E	150	350							142					PUB
158	SYDNOR, CHERRYDALE		E														PUB
159	TOTOPOTOMOY INC.	72	D	159	330	200	6					100	30				PUB
160	SYDNOR COLONIAL FORES	68	D	185	320		6					140	82	33	2.48	4	PUB
161	HENSLEY																DOM
162	HENSLEY				145												DOM
163	HANOVER WAYSIDE	37	D	180	196		6		191	195		121	100	53	1.88	24	PUB
164	SYDNOR	70	D	190	451	306	6		230	260		146	110	27	4.07	8	PUB
	SWANNANOA ESTATES																
165	SYDNOR RANIER ESTATES	70	DE	170	452		6		355	365		143	100	53	1.88	8	PUB
166	RICHMOND FOOD STORES	70	D	100	257	257	6		178	188		145	38	60	.63	12	COM
167	TOWN OF ASHLAND			220	700		8					3					ABD
168	SYDNOR, AVONDALE SUB	72	DE	165	362		6		246	256		143	100	105	.95	24	PUB
169	HUMBLE OIL CO.	71	D	205	250	86	6				PZPB	8	2	204		6	IND
170	NAT CEMETERY,COLD HAR			110	448							119					IND
171	SYDNOR, CHERRYDALE	72	D	190	394		6		344	384		178	110	56	1.96	24	PUB
172	EVA S PEMBERTON	37		184	150		2										DOM
173	R N PEMBERTON			150	160		6										DOM
174	R N PEMBERTON			150	200												DOM
175	R V LOWE	45		160	160		2										DOM
176	BATTLEFIELD PARK H S	35		190	195		6										INS
177	DOUGLAS FLEET	71	D	35	372		6	4	285	295		19	140	73	1.91	8	DOM
178	L.O. SNEAD	71	D	190	405	165	5					95	13	156	.08	7	DOM
179	TOTOPOTOMOY INC.	71	D	205	300	200											DST
180	SOUTH ANNA SERV CORP		D	170	287	13	6				GRGN	30	10	120	.08	2	PUB
	COUNTRY CLUB HILLS																
181	JOHN T SMOOK	60			150												PUB
	KOSMO VILLAGE																
182	HANOVER SCH FOR BOYS	51		102	210		8		185	206		55	110	87	1.26	32	DOM
183	LEE-DAVIS HIGH SCHOOL			165	292		6					132	50	43	1.16	24	INS
184	MONTPELIER SCHOOL			340	160		6				GRGN	60	15				INS
185	BATTLERFIELD PARK SCH	35		190	228		6					115	11	19	.57		INS
186	WASHINGTON HENRY	39		195	224		6		200	212		128	15	70	.21		INS
	ELEMENTARY SCHOOL																
187	BEAVERDAM ELEM SCHOOL	47		300	187		6				GRGN	60	35	60	.58		INS
188	BETHANY ELEM SCHOOL	58		345	168		6					30	40	75	.53		INS
189	EAST END ELEM SCH	59		190	292		6		247	262		100					INS
190	ROCKVILLE ELEM SCHOOL	65		280	150		6					80	10	40	.25	24	INS
191	DOSWELL SCHOOL	67		150	200		6					80	10	80	.12	24	INS
192	ELMONT ELEM. SCHOOL	67		260	225		6					60	50	100	.50	48	INS
193	THE FELDSPAR CORP.			235	160						GRGN						IND
194	FEARNOW BROS. CANNERY			190	50		30					30					IND

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T   DATE 11/28/78

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY   PAGE 7

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SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
195	FEARNOW BROS. CANNERY			190	50		30					30					IND
196	TOTOPOTOMY INC.	72	D	190	290	175	6				PZPB	80	30	170	.17	8	PUB
197	SYDNOR,ROBINS RIDGE	72	D	180	335		6		233	238		172	108	21	5.14	24	PUB
									296	316							
198	BEECHWOOD SERV CORP	73	D	110	310	68	6		136	216	PZPB	28	52	82	.63	19	PUB
	BEECHWOOD FARMS PW3																
199	VA. DEPT OF HIGHWAYS	56		20	241		6										GOV
200	HANOVER COUNTY				285		8					138					PUB
	BATTLEFIELD FARMS																
201	E M BLAKE DIANNE RIDG	73	D	165	439		6	5	419	439		156	69	64	1.07	24	PUB
202	SPEED & BRISCOE TRUCK	66		205	230	98	6						7	200	.03	12	COM
203	SPEED & BRISCOE TRUCK	66		205	190	98	6					22					COM
204	PEARSON CORNER SCH			195			6						8	150	.05		INS
205	B.P. OIL CORPORATION	72	D	130	200	21	6				PZPB	13	100	90	1.11	24	COM
206	WASHINGTON HENRY	72	D	195	431		6		411	431		180	41	24	1.70	5	INS
	ELEMENTARY SCHOOL																
207	SYDNOR HYDRODYNAMICS	72	D	150	346		6		223	228		143	22	105	.20	24	PUB
	HANOVER FARMS																
									312	322							
208	RICHMOND NAT. BTLFLD.			180													GOV
209	HANOVER VIL SHOP CTR	73	D	165	315		6		272	292		162	150	48	3.12	24	COM
210	AVONDALE CORPORATION	73	DE	165	325		6		242	252		164	105	39	2.69	24	PUB
211	BREMNER,YOUNGBLOOD	73	D		314		6		294	314		155	103	225	.45	34	PUB
212	FIBERLAY CORP.	73	D	150	357				50	70			10				IND
213	FIBERLAY CORP.	73	D	150	297		6					18	23	116	.19	12	IND
214	FIBERLAY CORP.	73	D	150	207						DRY						IND
215	FIBERLAY CORP.	73	D	150	400		6					18	6				IND
216	H T LOVING	73	D		150		6										PUB
217	EVANS PRODUCTS	73		140	200							52	65	116	.56	10	IND
218	JETER BROTHERS,INC																IND
	ASPEN HILL FARM																
219	SYDNOR HYDRODYNAMICS	73	DE	180	355		6		230	260			100	36	2.77	24	PUB
	MEADOWGATE SUB.																
220	HIGH POINT FARMS	73		170	345		6		310	340		180	95	43	2.20	24	PUB
221	JONES REALTY USGS WEL	74	EG	150	390		10										PUB
	USGS WELL																
222	KINGS DOMINION	74	D	145	420		6		170	200		20	1				PUB
223	NATKINS P CO., INC.			180													PUB
224	HANOVER ASSOCIATES	74	D		321		6						80	30	2.66	24	PUB
225	E H BAILEY REALTY	74	D		395		6		260	270			40			24	PUB
226	GENE B BROOKS	62		320			30										COM
	MOBIL STATION																
227	WALNUT GROVE DEV CORP	74	D	175	350		6		265	280		176	100	35	2.85	24	PUB
228	CHARLES EVERETT	74	D		370							26	2	370			PUB

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
229	J W BEAZLEY	64		290			30									DOM
230	SYDNOR #2 COL FORREST	74	S	190	330		6	256	276		157	80	16	5.00	24	PUB
					330		6							5.00	24	
231	C HOLLINS			180												
232	BRADLEY			225												
233	ANDREWS			200												
234	KEITH HALL,SR	70		335			30									COM
	SHELL STATION															
235	FLEMMING			300												COM
236	STANLEY			300												COM
237	GEORGE SWINSON	74			51						31					DOM
238	CHARLES HOLLINS	74		160	60						30					DOM
239	DAVID KIRBY	74			51						26					DOM
240	GARLAND L DOUGLAS	74		170	60						40					DOM
241	M R OWENS	74			46						22					DOM
242	JOHN E LEWIS III	73		190	35		30				16					DOM
243	DAVID WHEAT	74			48						28					DOM
244	JOSEPH F TWIGGS	74		200	39						14					DOM
245	V M MAXWELL	74			52						26					DOM
246	PETER GOETZ	74			68											DOM
247	MRS JAMES E MEADOW	74			54						30					DOM
248	GROOMES BROS REALTY	74			49						25					DOM
249	LAUREL CONG-JEHOV WIT	75	D	220	32		30				14					PUB
250	CHARLES W TALLEY	75	D		34		30				16					DOM
251	G L HOWARD INC	75	D		40		30				20					DOM
252	MARVIN MORRIS	75	D	300	47		30				25					DOM
253	W W & S R SMITH	75	D	230	40		30				20					DOM
254	CHESTER WALTERS	75	D	265	40		30				20					DOM
255	JOHN F HALDER	75	D	210	48		30				15					DOM
256	MAXIE DULING	75	D		45		30				28					DOM
257	CHESTER WALTERS	75	D		45		30				25					DOM
258	W S PERKINS	71			300		6				175	33	15	2.20	24	PUB
	HANOVER HGTS SUBDIV															
259	RICHMOND CRANE CO.	68	D	128	260	188	6					35			4	PUB
	ELLERSON IND PK#1															
260	STONEWALL ESTATES	72		190	410		6	272	282		185					PUB
262	OAK HILL ESTATES #3															PUB
263	E P TATE	50	D	190	48		30				20					DOM
264	C R HOPKINS	40	D	160	40		30									DOM
265	E G CROSS	30	D	185	40		36				35					DOM
266	W R WARRINER		D	200	50		2									DOM
267	R C DAWSON	75	D		37		30				21					DOM
268	A O HANCE	75	D		32		30				15					DOM
269	A O HANCE	75	D		42		30				20					DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T

DATE 11/28/78

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY

PAGE 9

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
270	WARREN BAUSERMAN	75	D		45		30					20					DOM
271	HENRY MILLS	75	D		34							20					DOM
272	W S PRIDDY	75	D		32		30					14					DOM
273	JOHN GARDNER	75	D		30		30					15					DOM
274	BRUCE CAUTHARNE	75	D		42		30					20					DOM
276	KEN MIDDLETON	75			39							20					DOM
277	COMMONWEALTH CONTRACT	75			34							14					DOM
278	B L DILLARD	74			59		30					34					DOM
279	SYDNOR MAYFIELD FM #3	75	DE	190	300		6		206	276		186	40	16	2.50	48	PUB
280	ARTHUR JOHNSON	75	D		45		30					22					DOM
281	MONROE DERRICK	75	D		42		30					20					DOM
282	R S POWELL	75	D		46		30					25					DOM
283	CHESTER WALTERS BUILDER	75	D		40		30					20					DOM
284	S L SPURRELL	75	D		42		30					28					DOM
285	MIKE LEADBETTER	75	D		43		30					24					DOM
286	NICKLAS BROTHERS	75	D	340	44		30					20					DOM
287	COX CONED CO INC	75	D		32		30					20					DOM
288	LEWIS L LOYD	75	D		42		30					20					DOM
289	LOGAN DYKE	75	D		41		30										DOM
290	A A WALSH	75	D		35		30					20					DOM
291	A A WALSH	75	D		30		30					15					DOM
292	BILL TAYLOR	75	D		38		30					20					DOM
293	W A GALLOWAY JR PRES	75	D		42		37	12				20	18				PUB
294	W A GALLOWAY JR PRES	75	D		367	160	6					155	20	180	.11	71	PUB
295	CALVARY PENTECOSTAL	75	D		165	35	6					28	15	160	.09	8	PUB
296	CALVARY PENTECOSTAL	75	D		250	35	6					26	10	250	.04	8	PUB
297	JAMES S GUILD	68		140	325		6										DOM
298	WILLIAM PEACE	51		60	300		6										DOM
299	J R HUCKSTEP	50		195													DOM
300	WILLIAM FULWIDER	62		185	50		36					20					DOM
301	SOUTHLAND CORP.	73		195													PUB
302	JESSE W BARR	38		175	28		24					25					DOM
303	THOMAS E CARTER	40		170	20		36										DOM
304	JOHN G CAMPBELL			165			36										DOM
305	MABEL WOOD & H WRIGHT	45		165	30		36										DOM
306	JACK BARKSDALE			185	42		30										PUB
307	CHARLES FRANCISCO	65		270	24		30					10					PUB
308	CHARLES FRANCISCO			310	52		30					25					PUB
309	C J TRAINHAM	63		210	36		30					24					DOM
310	G H HOLOWAY JR	73		285	40		30					6					PUB
311	E E EUBANK	65		350	55		30					33					DOM
312	J E COLLISON	74		110	30		36					17					DOM
313	D R FIELDS	69		116	33		36					13					DOM

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   W A T E R   C O N T R O L   M A N A G E M E N T DATE 11/28/78

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
314	JOE DUGGINS			136													DOM
315	C E DYSON	52		90	130		6					20					DOM
316	LESLIE W PARSLEY	69		170	70		36					20					DOM
317	G W WOOD	72		150	27		36					11					DOM
318	W D WELLS	56		170	40		36					12					DOM
319	FREDERICK HAYES SR.	60		175	50		36					30					DOM
320	CHESTER V HALL			160	35		30					15					DOM
321	EDDIE CLAYTOR			112	23		36										DOM
322	SYDNOR WALNUT GROVE#3	75	D	150	425	425	6		346	356		182	80	101	.79	48	COM
323	HARRY V KIRBY	75	D	340	30							16					DOM
324	A L FLETCHER	75	D		43		30					20					DOM
325	MILLER CONST CO	75			31		30					15					DOM
326	C A BURNETT	75	D		39		30					26					DOM
327	EVA HALL	75	D	320	30		30					14					DOM
328	WARREN S BAUSLIMAN	75	D		42		30					20					DOM
329	C LESTER JONES	75	D		46		30					20					DOM
330	WILLIS CAUTHORNE	75	D		45		30					18					DOM
331	LOTTIE BROWN	75	D		30		30					15					DOM
332	MARGARET KING	75		320	43		30					20					DOM
333	JOHN LLOYD	75	D		36		30					20					DOM
334	ROBERT M DOWDY	75	D		43		30					20					DOM
335	PARKER N LITTLE	75	D		30		30					15					DOM
336	WILSON DUKE	75	D		34		30					18					DOM
337	ROBERT LEWIS	75	D		42		30					20					DOM
338	JOHN WALDROP	75	D		44		30					20					DOM
339	DAN HAMILTON	75	D		47		30					20					COM
340	H L SIX	75	D		39		30					18					DOM
341	MR W M MERRETT	75	D	220	49		30					20					DOM
342	J W STANSBURG	75	D		24		30					10					DOM
343	SONNY SOUTHWORTH	75	D		24		30					12					DOM
344	FRANK BAKER	75	D	205	38		30					20					DOM
345	GARNETT NELSON	75	D		48		30					26					DOM
346	DAVID SMITH	75	D		27		30										DOM
347	ARTHUR JOHNSON	75	D		47		30					32					DOM
348	FIRST PREMIUM CORP	75	D		48		30					20					DOM
349	JAMES H WALKER	75	D		48		30					25					DOM
350	A Q HANCE	75	D		45		30					30					DOM
351	CHESTER WALTERS	75	D		43		30					20					DOM
352	RALPH ATKINSON	75			39							19					DOM
353	D W EDDLETON	75			50							25					DOM
354	MRS VIRGIL S HICKS	74			49												DOM
355	GROOMES BROS CON	74			41							16					DOM
356	M K WATSON JR	75			50							29					DOM
357	KWIK STOP FOOD STORE	75	D		150		6						15	150	.10		PUB

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

SUMMARY OF WATER WELL DATA FOR HANOVER COUNTY

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
358	JETER BROTHERS INC.	75	D	160	365		6				100	124			24	COM
359	DOUG MIDDLETON	75			49						29					DOM
360	J W CARNELIUS	75			46						23					DOM
361	JOSEPH TWIGG	75			55						25					DOM
362	C E ESTES	75			40						22					DOM
363	VIRGINIA HUNDLEY	75			46						20					DOM
364	RAYMOND O HERRING	75			42						20					DOM
365	R B DANDRIDGE	75			41						21					DOM
366	ALVIN TIGNOR			335			36									COM
367	ROBERT WINSTON			315	47											DOM
368	J HORWOOD COCHRAN			303												COM
369	CALVIN MEAD			299	300											DOM
370	D A STANLEY			293			30									DOM
371	MR JOHN FIGULY	11		163	60		30									DOM
372	HERMAN LUKHARD			145			30									DOM
373	P L JONES	80		150	50		36									DOM
374	JOHN MAPLES	69		225	430		6									DOM
375	W A FLEET	75		185	60		30									DOM
376	A E GAULDING JR	80		125	30						20					DOM
377	C B WILLIAMS	69		75	285		8				85					DOM
378	J E HOLMES	60		180	45		30									DOM
379	VA INDUSTRIAL SCHOOL	50		190	300											INS
380	S J BRANNAN	31		170	30		36									DOM
381	M K KIRBY	59		170			36									DOM
382	W WINFIELD	69		180	90		30									DOM
383	W H FLAGG	70		200	50		36									DOM
384	MR T R NEWTON			200	40		36									DOM
385	MR W H MADDOX	50		295	35		36									DOM
386	B A MILES			303			30									DOM
387	AUBERY STAUNLEY			215	40		30									DOM
388	J P NEWCOMER			293			36									DOM
389	MR LOWERY	25		255	20		36									DOM
390	MRS WILLIAM KOCTT	75	D		75		6				8	100			4	PUB
391	FRANK STONE	75	D		36		30				10					DOM
392	GROOMES BROS CONST	75			43						23					DOM
393	MARVIN MORRIS	75	D		50		30				25					DOM
394	LINDSEY GLASCOW	75	D	230	20		30				10					DOM
395	LEWIS HENLY	75	D		34		30				15					DOM
396	R J BARKSDALE	75	D		29		30				15					DOM
397	L F HALL	75	D		20		30				14					DOM
398	JACK CALLISON	75	D		22		30				12					DOM
399	MARVIN WEEKS	75	D		22		30				12					DOM
400	L HENDERSON	75	D		20		30				10					DOM
401	RUBY VAUGHN	75	D		29		30				15					DOM

SWCB NO	OWNER AND/OR PLACE	YEAR COMP	LOG	ELEV	TOTAL DEPTH	BED-ROCK	CASING MAX	CASING MIN	DEVEL FROM	ZONE TO	AQUIFER	STATIC LEVEL	YIELD	DRAW DOWN	SPEC CAPAC	HRS	USE
402	JAMES FERGERSON	75	D		37		30					20					DOM
403	GROOMES BROS CONST	76			46							26					DOM
404	W W KELLUM	76			41		30	24				16					DOM
405	W W KELLUM	76			53		30					33					DOM
406	W W KELLUM	76			41		30					11					DOM
407	MR M FAIN	75			40							20					DOM
408	ERICH PELSCHANGER	75			52							32					DOM
409	C E DAVIS	75			53												DOM
410	MRS LISBORNN	76			48		30					31					DOM
411	KEN MIDDLETON				48		30										DOM
412	LE'REVE MANOR R JETER	76	D	185	382		6	6	346	352		175	120	90	1.33	48	PUB
413	ROBERT C CLARK	76	D		250	23	6	6				28	5			1	DOM
414	ITAL, KITCHEN-AIGNER	76	E	170	316		6	4	280	290		167	47	16	2.93	24	COM
415	H L SEAL	77			380		6	4				36	40	117	.34	1	DOM
416	FRED D. THARPS	77	E		306		4		242	247		98	20	223	.08	1	DOM
417	COUNTY OF HANOVER	75	CN	548		96											DOM
418	INVESTORS MANAGEMENT	77	DE	180	328		6		216	236		150	55	36	1.52		DOM
419	ROY ROGERS DEV.CORP.	77	DE	165	360		6	4	262	267		189	45	42	1.07	48	PUB
420	ROY ROGERS DEV CORP	77	DE		334		6	4	284	324		160	90	32	2.81	48	PUB
421	COUNTY OF HANOVER	77	DEG	190	210												ABD
422	HANOVER WATER COMPANY	77	DE	170	402		6					163	8	82	.09	2	PUB

APPENDIX III

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S   DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR   HANOVER COUNTY   PAGE 2

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
2	MEADOWBRIDGE #1	12 68	8.4				19	0.02	0.00	6.0	1.2	110.3		207	6.2	42.0	0.4
3	MAYFIELD FARMS #1	2 69	8.0			127		1.72	0.07	24.0					33.0	6.5	0.0
4	MAYFIELD FARMS #2	2 69	8.6			133	70	0.55	0.01	28.0					28.0		0.9
6	MEADOWGATE #1	10 71	8.4			86	68	0.03	0.03	27.3		10.5	15.5		10.1		0.9
7	AVONDALE #1	10 71	8.5			135	104	0.01	0.01	41.7		20.5	10.0		11.9		0.0
7	AVONDALE #1	4 74	7.6	358		135	93	0.10	0.01	37.5	10.9	21.0	9.4		15.6	5.5	
8	RICHMOND FOOD STORES	1 74	9.0	805	565	20	11	0.08	0.00	4.8	2.0	183.0	12.0		46.4	15.0	0.4
8	RICHMOND FOOD STORES	12 72	8.6			36	19	0.11	0.05	7.6	4.1	205.0	14.0			95.8	6.2
9	RICHMOND FOOD STORES	1 74	8.2	272	227	122	122	0.39	0.03	30.8	11.0	17.5	10.0		9.2	8.0	0.0
9	RICHMOND FOOD STORES	12 72	8.4			122	80	0.26	0.05	32.0	10.2	21.0	11.5			1.5	0.0
10	CRANEY ISLAND ESTATES	3 72				234	146	0.38	0.04	58.5	21.3						
10	CRANEY ISLAND ESTATES	4 69	8.3			212		0.00	0.01	54.5						78.5	
10	CRANEY ISLAND ESTATES	12 66	7.3		763		194	0.08		61.0	10.3	172.5			38.7	211.0	1.8
10	CRANEY ISLAND ESTATES	4 66	7.5				153	0.45	0.00	47.0	8.8	56.7		280	14.4	21.0	3.5
10	CRANEY ISLAND ESTATES	12 65	8.3				98	1.30	0.00	32.0	4.6	86.7		202	17.3	75.0	3.5
10	CRANEY ISLAND ESTATES	12 65	7.6				134	0.20	0.00	41.0	7.8	482.0		229	221.0	544.0	4.4
13	HANOVER FARMS	9 66	8.3				4	0.00	0.00	1.3	0.1	63.0		117	25.1	3.0	1.8
15	CHERRYDALE	2 72	7.7		166	72	42	0.20	0.00	16.8	7.2	15.0	1.8		14.1	1.0	0.9
15	CHERRYDALE	6 68	7.7				74	0.06	0.00	17.0	7.6	25.6		129	15.6	5.0	0.4
17	MOBIL CHEMICAL	6 73	7.6			97		0.70	0.47							23.5	0.0
17	MOBIL CHEMICAL	6 73	6.9			96		0.50	0.64								
17	MOBIL CHEMICAL	5 75	6.7			100	85	1.00	0.50	27.8	6.0	8.3	2.3			21.0	0.0
17	MOBIL CHEMICAL	9 70	6.4			61	54	0.66	0.02	21.6					22.9	8.5	
17	MOBIL CHEMICAL	9 64	8.2				59	0.70		17.0	4.1	9.6		78	12.6	5.0	
18	MOBIL CHEMICAL	6 73	7.6			98		0.54	0.64								
18	MOBIL CHEMICAL	35 73	7.6			99	98	9.00	0.63	28.1	7.0	10.8	3.3			19.0	0.0
18	MOBIL CHEMICAL	4 73	7.4				91	0.01	0.48	26.3	16.8	16.8		80	33.3	20.0	1.8
18	MOBIL CHEMICAL	1 73	7.5		164	78	79	2.10	0.30	23.7	4.6	8.0	2.1		39.2	15.1	0.4
18	MOBIL CHEMICAL	11 70	6.7			80		2.88	0.11						23.5	9.0	
18	MOBIL CHEMICAL	9 67	6.9				64	0.80	0.00	16.5	5.5	5.8		80	3.3	6.0	1.3
38	HIGH POINT FARMS	3 74	8.2	92	142	54	51	0.12	0.02	12.0	5.1	11.0	21.0		14.1	1.0	0.0
39	OAK HILL ESTATES	10 62	8.1				58	0.10		10.0	7.9	38.6		168	8.2	7.0	5.3

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES — DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR HANOVER COUNTY — PAGE 3

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
40	OAK HILL ESTATES	6 73	7.8	204	154	30	30	0.20	0.07	6.0	3.5	32.5	6.0		8.8	2.0	0.0
40	OAK HILL ESTATES	9 63					44	0.30	0.00	6.8	6.7	44.6		158	7.4	7.0	4.0
47	BEECHWOOD FARMS	4 74	7.7		453			0.11	0.10						58.0		
47	BEECHWOOD FARMS	1 72	8.3		440	119	66	0.06	0.12	26.4	12.8	110.0	15.0		76.0	43.5	0.9
49	ASPEN HILL FARMS	3 72	8.2			81		0.22	0.00								
51	WINDY HILLS	4 62	8.1				56	0.05	0.00	38.1	15.2				11.8	14.3	0.0
55	H N PERKINS	8 74	6.9	337		220	218	7.00		58.0	17.9	17.8	7.1		10.6	8.0	0.0
60	DOGWOOD KNOLL	9 72	7.8		163	75	46	0.42	0.00	18.4	7.0	14.5	17.0		15.0	0.5	0.0
61	DOGWOOD KNOLL	8 72	7.8		154	69	44	0.20	0.16	17.6	6.0	16.4	1.6		15.7	0.5	2.7
61	DOGWOOD KNOLL	6 62	7.8				69	0.20		16.0	7.1	26.2		131	10.3	7.0	0.4
65	HOLLY RIDGE	7 74	7.8	375	342	166	173	0.20	0.04	43.5	15.8	22.0	18.3		13.0	4.5	0.0
65	HOLLY RIDGE	8 73	8.0	352	278	165	171	0.20	0.01	44.0	15.0	22.0	13.0		15.6	4.5	0.0
69	LEADBETTER CONST CO	4 70	5.4				4	0.08	0.00	0.4	0.4	7.8		14	1.2	6.0	0.0
70	BRANDY CREEK	8 72	8.1		210		58	0.06	0.10	23.2	4.3	25.5	2.3		26.2	1.5	5.8
70	BRANDY CREEK	3 69	7.7				71	0.15	0.00	18.0	6.4	21.9		126	9.1	4.0	0.9
74	J P BARRETT SCHOOL	6 73	7.9	317	212	120	122	0.10	0.09	37.5	6.8	16.4	8.2		15.7	13.0	0.0
76	BEAVERDAM PARK	2 74	8.2	329	197	29	29	0.44	0.05	6.3	3.3	48.5	18.0		10.4	2.0	0.0
76	BEAVERDAM PARK	2 74	8.5	340			29	0.42	0.05	6.1	3.4	48.0	17.7		10.9	2.0	4.9
76	BEAVERDAM PARK	1 74	8.5	264	182	38	37	0.04	0.02	9.4	3.3	49.0	18.0		22.4	4.5	0.0
76	BEAVERDAM PARK	1 74	8.3	306	192	35	36	0.23	0.36	7.8	3.6	50.0	28.0		25.2		0.0
116	BURNSIDE FARMS	11 73	8.1	395	327	147	151	0.17	0.03	36.0	15.1	36.5	14.5		50.4	6.0	0.9
116	BURNSIDE FARMS	1 57	7.4				122	0.40								7.0	
117	CRANEY ISLAND ESTATES	3 72				217	216	0.47	0.10	56.1	18.7						
117	CRANEY ISLAND ESTATES	1 69	7.5		344	193		0.88	0.13	32.9		38.0			11.0	16.0	0.0
117	CRANEY ISLAND ESTATES	2 60	7.8				226	0.63	0.17	63.1	16.7	25.3			31.2	7.5	
119	BLUE STAR ESTATES	6 74	7.5			218		0.25	0.09						32.0	84.0	
119	BLUE STAR ESTATES	5 74	7.8	278		202		0.55	0.09							33.5	0.4
119	BLUE STAR ESTATES	4 74	7.6				219	0.16	0.05	37.4	18.3	32.6		280	15.8	31.0	2.2
119	BLUE STAR ESTATES	8 73	7.8	402	326	197	206	0.27	0.09	58.5	14.6	25.2	7.0		12.7	15.5	0.0
119	BLUE STAR ESTATES	4 72	8.1		315	199	198	0.06	0.02	57.7	13.3	20.0	7.3		10.6	9.5	1.8
119	BLUE STAR ESTATES	10 65	7.8				195	0.10	0.39	63.5	8.9	188.1			86.0	231.0	

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S   DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR   HANOVER COUNTY

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
119	BLUE STAR ESTATES	9 65	7.9				168	0.30		53.0	8.7	40.2			14.0	24.0	
119	BLUE STAR ESTATES	4 65	7.9				332	1.44	0.18	78.3	33.3	195.2			137.8	320.1	
123	MECHANICSVILLE #1	8 61	7.8					0.09	0.00							1.6	
124	MECHANICSVILLE #2	8 61	7.6					0.18	0.00							2.0	
125	MECHANICSVILLE #3	8 61	8.1					0.20	0.00							205.3	
127	EVANS PRODUCTS	9 69	8.3				19	0.10	0.00	4.5	1.9	67.2		170	0.2	6.0	0.9
129	EVANS PRODUCTS	10 69					114	0.04	0.00	29.7	9.8	83.6		185	1.6	1.6	1.3
151	SPRING MEADOWS SUB	7 70	7.7				93	0.01		23.0	8.9	26.0	20.0		26.0	6.2	
151	SPRING MEADOWS	6 68	7.4			105		0.30	0.03	25.6		19.0					0.0
151	SPRING MEADOWS SUB	3 59	7.9					0.28	0.00							2.5	
152	SPRING MEADOWS SUB	7 70	7.7				92	0.01		22.0	9.2	25.0	20.0		25.0	5.1	
152	SPRING MEADOWS	6 68	7.3			80		0.18	0.03	17.6		18.0					0.0
153	SPRING MEADOWS	6 68	7.0			61		0.01	0.01	12.8							2.7
153	SPRING MEADOWS	4 65	8.3				34	0.20		10.0	2.1	28.1		87	12.3	6.0	
154	OAK HILL ESTATES	6 73	7.9	322	226	35	35	0.23	0.07	7.8	3.8	70.0	7.0		1.8	3.5	0.0
154	OAK HILL ESTATES	7 68	7.8				15	0.15	0.00	4.5	1.1	86.5		224	0.8	8.0	0.4
154	OAK HILL ESTATES	6 68	7.2		230	33	32	0.76	0.22	6.4	4.0				1.6	4.0	0.0
155	OVERHILL FARM SUB	4 59	6.8					0.16	0.08							2.0	
157	OLD CHURCH	12 72	7.8				23	0.03		5.9	2.2	48.0	19.0		10.0	1.9	
160	COLONIAL FOREST	9 74	8.0			187		0.28	0.05							6.0	
160	COLONIAL FOREST	11 72	7.7				121	0.26		36.0	7.6	12.0	9.0		11.0	5.9	
160	COLONIAL FOREST	2 73	7.9		198	125		0.12	0.04			11.0	7.5		8.0	5.2	0.0
160	COLONIAL FOREST	4 68	7.8				121	0.20	0.02	36.5	7.4	10.2		158	5.3	6.0	0.4
165	RANIER ESTATES	9 73	7.8	220	184	4	5	0.46	0.00	1.2	0.4	46.0	26.5		18.2	2.0	0.0
165	RAINIER ESTATES	11 72	7.6				5	0.44		1.2	0.6	45.0	26.0		21.0	2.0	
165	RANIER ESTATES	6 70	7.7				6	0.08	0.00	1.5	0.6	54.9		134	8.2	5.0	0.9
166	RICHMOND FOOD STORES	1 74	8.3	298	231		130	0.06	0.03	32.0	12.2	20.2	11.0		15.0	1.0	0.0
166	RICHMOND FOOD STORES	12 72	8.4			129	128	0.50	0.24	31.2	12.3	27.0	12.0			2.0	3.1
166	RICHMOND FOOD STORES	1 71	7.3				120	0.93	0.04	30.1	11.1	18.4		190	2.1	3.0	3.5
170	OLD COLD HARBOR CEM	8 71	7.7				59	0.09		15.0	5.4	17.0	21.0		10.0	2.0	
171	CHERRYDALE #2	6 74	7.2	220	136	62	65	0.26	0.04	16.0	6.3	11.0	17.6		11.2	0.5	0.0

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S   DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR   HANOVER COUNTY   PAGE 5

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
171	CHERRYDALE #2	8 72	8.3				74	0.22	0.00	14.0	9.5	18.2		107	10.9	2.0	0.0
172	GUM TREE	8 71	6.7				36	0.68		8.3	3.8	10.0	6.0		9.0	2.8	
173	GUM TREE	8 71	6.7				44	0.14		8.5	5.7	15.0	7.9		18.0	8.8	
176	BATTLEFIELD PARK SCH	8 71	7.7				70	0.07		19.0	5.6	18.0	25.0		11.0	2.2	
182	HANOVER SCH FOR BOYS	6 73	8.0	317	204	111	112	0.41	0.10	28.1	10.3	18.8	12.5		10.2	11.5	0.0
182	HANOVER IND SCHOOL	3 52	7.9				134	0.20	0.06	37.6	10.0				7.2	15.8	
182	HANOVER SCH FOR BOYS	7 38	7.4				136	0.15						215		3.0	
197	ROBIN RIDGE	4 74	7.7		228	135		4.97	0.14	38.6			7.9		9.7	0.5	0.0
197	ROBIN RIDGE	4 74	7.8	374	233	122		0.00	0.01	39.1			9.6		14.0	1.0	0.4
197	ROBIN RIDGE	4 74	7.7	347	252	141	153	0.03	0.00	41.2	12.4	20.0	10.7		16.5	5.5	0.0
197	ROBIN RIDGE	4 74	7.6	347	240	133	132	10.50	0.18	36.4	10.0	14.0	7.9		5.5	5.0	0.0
197	ROBIN RIDGE SUB	11 72	7.5				150	0.00		42.0	11.0	19.0	8.8		6.2	5.2	
197	ROBIN RIDGE	4 72	7.4				136	0.11	0.00	31.8	13.9	26.8		222	1.6	8.0	0.0
198	BEECHWOOD FARMS	4 74	7.8		448			0.09							58.0		
198	BEECHWOOD FARMS	2 74	8.5	568				0.13	0.13						41.2		
198	BEECHWOOD FARMS	1 74	8.2	600				0.35	0.12								
198	BEECHWOOD FARMS	5 73	7.9		466	145	148	0.30	0.10	31.8	16.6	98.0	18.0		43.2	58.0	0.0
198	BEECHWOOD FARMS	5 73	8.2				55	0.01	0.00	7.6	8.9	192.8		295	84.8	97.0	0.0
199	VDH,OLD CHURCH	8 71	7.7				137	0.11		37.0	11.0	10.0	24.0		9.2	2.8	
200	BATTLEFIELD FARMS	2 59	7.8					0.52	0.05							2.0	
201	DIANNE RIDGE	3 74	8.4	271	198	5	4	0.27	0.00	1.0	0.2	59.5	9.5		12.6	0.5	0.0
201	DIANNE RIDGE	1 74	8.4	241			4	0.49	0.02	1.3	0.3	57.0	5.5		0.0	0.7	0.0
202	SPEED & BRISCOE #4	4 66	8.4				178	0.07	0.10	71.3	0.2				2.6	4.5	
203	SPEED & BRISCOE #5	4 66	8.4				173	0.25	0.25	69.1	0.3				3.6	4.0	
204	PEARSON ELEM SCHOOL	12 72	7.7				124	0.02		35.0	9.0	16.0	7.3		12.0	4.4	
207	HANOVER FARMS	9 72	8.3		196	3		0.02	0.00		0.2	51.0	3.4		19.2	1.5	0.0
208	GARTWRIGHT HOUSE	2 68	7.1				52	0.02		20.8	0.2	1.4			0.1	26.5	
209	HANOVER VILLAGE	3 74	8.0	272	192	91	86	0.32	0.05	19.0	9.1		18.5		28.7	2.0	0.0
210	AVONDALE #3	5 73	8.1				142	0.20	0.07	31.3	15.7	22.6		202	10.3	11.0	4.4
213	FIBERLAY CORP WELL #3	8 73			268	78	78	0.01	0.05	15.8	9.5	185.4			7.4	52.0	

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VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR HANOVER COUNTY PAGE 6

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
218	ASPEN HILLS #2	1 75	7.4				38	0.08			5.3	6.1		49	5.0	0.0	17.7
218	ASPEN HILLS #2	10 74	7.8	260	167	52	56	1.20	0.04	11.2	6.3	31.0	23.2		21.0	3.5	0.0
218	ASPEN HILLS #2	10 73	7.8				57	0.04	0.00	11.3	6.6	39.8		148	16.7	3.0	0.0
219	MEADOWGATE #2	10 73	7.8				106	0.12	0.00	19.6	13.3	22.5		173	6.6	3.0	0.0
220	HIGH POINT FARMS #2	4 74	7.6				36	0.30	0.01	9.1	3.3	30.5	29.0		16.4		0.0
220	HIGH POINT FARMS #2	3 74	7.7		163	42	44	0.45	0.02	10.5	4.1	26.0	25.5		17.3	0.5	0.0
220	HIGH POINT FARMS #2	9 73	7.5				59	0.01	0.00	11.4	7.5	39.6		148	18.3	3.0	0.0
223	NATKINS	12 72	6.7		111	28	27	1.30	0.02	8.8	1.4	1.2	3.1		8.6	5.7	0.4
223	NATKINS	4 73	7.1		83	29	25	1.10	0.17	7.9	1.4	6.7	2.1		11.8	5.5	0.0
224	GEORGETOWN #1	5 74	8.6	293	194	94	96	0.39	0.03	29.9	5.4	25.5	6.6		13.0	1.0	0.0
225	SINCLAIR MANOR	5 74	8.5	210	166	12	13	0.13	0.00	3.7	1.0	49.0	0.7		12.9	0.5	0.0
226	GENE B BROOKS MOBIL	12 74	6.0				27	0.10		6.0	3.0	2.8	3.4		1.2	4.0	22.2
229	J W BEAZLEY	12 74	6.6	220			46	0.10		16.0	1.6	30.0	2.0		1.5	39.0	31.0
230	COLONIAL FOREST #2	5 74	6.9				130	0.09	0.06	25.1	16.4	16.3		180	6.6	8.0	0.0
231	C HOLLINS	8 74	7.2	235			141	0.20		43.0	8.2	13.5	8.5		9.8	6.0	0.0
232	BRADLEY WELL	6 74	6.0	40			12	0.00		4.0	0.5	5.0	1.1		0.0	4.0	3.1
233	ANDREWS WELL	6 74	6.5	100		38	43	0.10		12.0	3.3	8.0	2.7		6.6	4.0	0.4
234	KEITH HALL SR	12 74	6.4	69			38	0.10		13.0	1.5	4.1	0.2		1.0	2.0	0.4
235	FLEMMING WELL	6 74	8.2	155				0.10	0.90	32.0		5.5	3.6		10.2	6.0	1.3
236	STANLEY WELL	6 74	5.9	35		10		0.10	0.90	4.0		4.0	1.7		3.8	4.0	0.0
258	HANOVER HTS SOUTH	6 73	8.3			181		0.40	0.07							6.5	
258	HANOVER HTS SOUTH	7 72	8.1		296	177	176	0.28	0.10	50.5	12.3	17.5	9.1		22.0	0.5	0.4
258	HANOVER HTS SOUTH	9 71	7.3		278	161	161	0.18	0.03	44.1	12.4					5.0	
259	ELLERSON IND PARK	11 73	7.4	293	223	112	113	0.05	0.00	25.5	12.1	27.5	13.0		11.9	3.5	0.4
259	ELLERSON IND PARK	3 70	6.9			107		0.65	0.03	24.0		8.2			17.5	3.5	0.0
260	STONEWALL ESTATES	9 74	8.3	290	159	58	42	0.34	0.04	10.3	3.7	37.0	29.4		13.2	13.0	0.0
260	STONEWALL ESTATES	8 74	8.9	210	170	41	36	0.15	0.03	7.5	3.8	25.0	21.0		13.2		0.0
260	STONEWALL ESTATES	5 74	8.1	259	173	27	26	0.09	0.04	5.0	3.2	24.5	24.5		12.5	1.0	0.0

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V I R G I N I A   S T A T E   W A T E R   C O N T R O L   B O A R D

B U R E A U   O F   S U R V E I L L A N C E   A N D   F I E L D   S T U D I E S   DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR   HANOVER COUNTY   PAGE 7

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SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
260	STONEWALL ESTATES	5 74	8.1	279	173	34	44	1.78	0.03	8.9	2.9	27.0	30.0			0.5	0.0
260	STONEWALL ESTATES	2 74	7.6	212	164	35	38	1.37	0.03	8.4	3.4	22.0	25.0		13.4	0.5	0.0
260	STONEWALL ESTATES	6 73	7.7				13	0.17	0.00	4.8	0.0	100.6	20.2	61	5.8	0.0	0.0
261	OAK HILL ESTATES #5	6 73	7.8	215	170	20	19	0.04	0.07	3.8	2.3	39.5	6.3		5.2	2.0	0.0
262	OAK HILL ESTATES #3	4 65	6.9				57	0.60	0.00	9.5	8.3	22.1		117	4.7	5.0	4.0
264	GREEN TOP SER STA	3 75	5.6	130			72	0.10		21.0	4.8	10.0	2.3		4.1	13.0	46.5
265	E G CROSS	3 75	5.7	340			67	1.10		17.0	6.0	62.0	2.5		5.4	103.0	33.2
266	W R WARRINER	3 75	5.6	51			28	0.10		8.0	2.1	3.9	1.5		6.8		12.0
297	JAMES S GUILD	7 75	7.2	255			17	0.30		5.0	1.3	59.0	6.2		1.8	1.0	0.0
298	WILLIAM PEACE	7 75	7.3	281											1.8	4.0	0.0
299	J B HUCKSTER	7 75	6.0	259			58	0.10		18.0	3.4	15.0	2.1		1.5	38.0	12.4
300	WILLIAM FULWIDER	7 75	5.3	109			29	0.00		5.0	4.2	6.1	2.9		1.8	7.0	33.2
301	SOUTHLAND CORP	7 75	6.1	62			19	0.00		6.0	1.1	3.4	1.8		2.0	4.0	5.8
302	JESSE W BARR	6 75	5.5	63			16	0.00		1.0	3.4	4.7	1.6		0.8	5.0	17.7
303	THOMAS E CARTER	6 75	6.9	260			82	0.50		28.0	3.1	20.0	5.1		28.3	24.0	31.0
304	JOHN G CAMPBELL	6 75	5.0	330			21	0.20		3.0	3.4	53.0	41.0		23.1	57.0	39.9
305	MABEL WOOD & H WRIGHT	6 75	5.7	90			11	0.00		2.0	1.7	13.2	0.8		0.8	8.0	22.2
306	JACK BARKSPALE	6 75	5.8	140			42	0.00		11.0	3.6	12.1	3.7		1.2	16.0	28.8
307	CHARLES FRANCISCO	6 75	5.9	140			46	0.00		15.0	2.3	12.8	1.6		1.5	22.0	6.6
308	CHARLES FRANCISCO	6 75	6.9	140			65	0.00		25.0	0.8	7.5	1.9		0.0	7.0	4.4
309	C J TRAINHAM	6 75	6.1	250			48	0.00		9.0	6.3	44.0	4.5		3.5	54.0	28.8
310	G M HOLOWAY JR	6 75	6.9	60			24	0.00		9.0	0.5	30.0	2.1		3.4	2.0	4.4
311	E E EUBANK	6 75	6.4	85			40	0.20		15.0	0.7	60.0	0.6		0.9	7.0	5.3
312	J E COLLISON	7 75	6.1	260			86	1.10		28.0	4.1	16.0	5.0		36.5	15.0	4.9
313	D R FIELDS	7 75	5.8	60			18	0.60		6.0	0.8	4.5	0.3		1.2	2.0	0.9

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VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES — DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR HANOVER COUNTY — PAGE 8

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
314	JOE DUGGINS	7 75	4.6	95		29	0.10		6.0	3.5	2.9	1.4		5.9	3.0	31.0
315	C E DYSON	7 75	5.7	89		29	0.10		7.0	2.9	5.4	0.7		6.3	6.0	13.7
316	LESLIE W PARSLEY	7 75	5.7	150		42	0.30		12.0	3.1	24.0	1.2		1.2	19.0	39.9
317	G W WOOD	7 75	5.9	62		21	0.00		6.0	1.6	4.7	1.4		0.9	5.0	12.8
318	W D WELLS	7 75	5.6	65		22	0.10		7.0	1.2	8.6	0.5		1.1	5.0	4.4
319	FREDERICK HAYES SR	7 75	5.6	33		14	0.10		5.0	0.5	3.6	0.5		0.3	4.0	1.8
320	CHESTER V HALL	7 75	6.0	110		43	0.20		12.0	3.4	7.0	2.3		0.4	5.0	26.6
321	BEDDIE CLAYTON	7 75	5.5	74		24	0.10		9.0	0.5	6.6	0.6		2.4	5.0	0.9
366	ALVIN TIGNOR	8 75	6.7	108		51	0.10		18.0	1.7	1.0	0.8		2.3	3.0	1.3
367	ROBERT WINSTON	8 75	6.1	81		41	0.00		15.0	0.9	0.0	1.9		3.2	1.0	1.3
368	J HORWOOD COCHRAN	8 75	6.5	6		25	0.20		6.0	2.5	2.0	81.1		3.8	3.0	0.0
369	ALVIN MEAD	8 75	7.2	300		146	2.40		40.0	11.3	8.0	3.5		3.9	7.0	0.0
370	B A STANLEY	8 75	6.0	190		33	0.20		9.0	2.7	18.0	5.8		18.5	36.0	8.4
371	JOHN FIGULY	11 75	5.5	62		21	0.00		5.0	2.2	1.0	0.5		0.0	7.0	19.9
372	HERMAN AUKARD	11 75	5.9			29	0.00		9.0	1.8	1.0	2.3		1.4	15.0	10.6
373	P L JONES	11 75	5.2	142		22	0.00		3.0	3.6	9.0	3.4		0.0	37.0	17.7
374	JOHN MAPLES	11 75	7.2	276		7	0.00		2.0	0.6	7.1	8.8		4.7	1.0	0.4
375	W A FLEET	11 75	6.6	284		172	0.00		66.0	1.8	1.0	2.0		7.4	10.0	0.0
376	A E GAULDING JR	6 75	5.3	45		13	0.20		3.0	1.4	4.0	0.9		2.0	4.0	1.8
377	C B WILLIAMS	6 75	7.6	240		3	0.10		1.0	0.2	66.0	3.1		12.3	1.0	0.0
378	E HOLMES	3 75	5.6	53		30	0.20		9.0	1.9	2.2	3.9		7.8	9.0	2.7
380	S J BRANNAN	11 75	6.2	86		28	0.00		9.0	1.5	6.0	0.3			9.0	31.0
381	M K KIRBY	11 75	5.9	92		24	0.00		8.0	1.0	1.0	0.0			12.0	16.8

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VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF SURVEILLANCE AND FIELD STUDIES

DATE 01/08/79

SUMMARY OF GROUNDWATER QUALITY ANALYSES FOR HANOVER COUNTY

PAGE 9

SWCB NO	OWNER AND/OR PLACE	DATE SAMP	PH	SPEC COND	T-DIS SOLID	HARDNESS TOTAL	HARDNESS CA,MG	FE	MN	CA	MG	NA	K	HCO3	SO4	CL	NO3
382	W WINFIELD	11 75	5.9	146			45	0.20		11.0	4.5	1.0	10.5			12.0	57.6
383	W H FLAGG	11 75	5.8	49			23	0.00		8.0	0.9	1.0	0.0			8.0	0.0
384	T R NEWTON	11 75	4.9	47			16	0.20		5.0	0.9	1.0	1.4			3.0	0.4
385	W H MUDDOX JR	11 75	6.1	110			47	0.00		18.0	0.7	1.0	0.2			9.0	12.0
386	B A MILES JR	11 75	5.4	225			42	0.20		2.0	9.2	30.0	2.7			46.0	57.6
388	J P NEWCOMER	11 75	5.5	44			18	0.00		5.0	1.5	1.0	1.1			4.0	7.1
389	MR LOWERY	11 75	6.1	190			100	0.00		23.0	10.5	5.0	0.9			22.0	17.7
424	LEROY RICE	9 77	6.9	200		78	81			26.0	4.0	6.0	3.0		12.0	11.0	
425	W E PEACE	9 77	7.7	260		76	76	0.40	0.03	19.0	7.0	26.0	23.0		9.0	3.0	
426	BEASELY STORE	9 77	6.7	210		24	34		0.02	12.0	1.0	34.0	2.0		2.0		
427	FARMER	9 77	5.9	71		12	25			7.0	2.0	5.0	2.0		2.0	2.0	
428	NEWCOMER	9 77	5.8	35		12	6	0.10		1.0	1.0	3.0	2.0		2.0		
429	JO ANN ORREK	9 77	6.8	150		38	67			22.0	3.0	8.0	3.0		2.0	8.0	
430	C E WAMPLER	9 77	6.6	180		54	77			21.0	6.0	7.0	1.0		2.0	13.0	
437	BEREA BAPTIST	9 77	7.1	440		212	206	0.40	0.09	53.0	18.0	21.0	2.0		5.0	66.0	
432	COUNTRY CORNER	9 77	7.7	410		120	137	0.70	0.04	37.0	11.0	55.0	3.0		4.0	22.0	
433	B A STANLEY	9 77	6.3	175		32	25	0.50	0.05	7.0	2.0	26.0			7.0	37.0	

NOTE--ALL ZEROS (00.00) - ANALYSED, NOT DETECTED; ALL NINES (99.99) - COULD NOT BE STORED, REFER TO ANALYSIS

APPENDIX IV

GLOSSARY OF TERMS

ALLUVIUM:	A general term for sediments deposited during recent geologic time by a stream or other body of water.
AMPHIBOLITE:	A crystalloblastic (metamorphic) rock consisting mainly of amphibole and plagioclase with little or no quartz.
APATITE:	A group of variously colored hexagonal minerals consisting of calcium phosphate together with fluorine, chlorine, hydroxyl, or carbonate in varying amounts and having the general formula: $Ca_5(PO_4, CO_3)_3(F, OH, Cl)$.
AQUICLUDE:	A geologic formation, group of formations, or part of a formation, which is not permeable enough to transmit groundwater, nor does it contain water.
AQUIFER:	A geologic formation, group of formations, or part of a formation capable of supplying water to wells and springs in usable quantities. An aquifer is unconfined (water table) or confined (artesian) depending on whether the groundwater level is at atmospheric pressure or greater than atmospheric pressure due to the presence of an overlying, confining geologic formation (aquiclude or aquitard).
AQUITARD:	A formation that partially restricts groundwater flow, but will not yield water to a well.
ARTESIAN AQUIFER:	A confined aquifer in which groundwater rises in a well above the point at which it is found in the aquifer.
ARTESIAN WELL:	A well in which the water rises under artesian pressure above the top of the aquifer the well penetrates, but does not necessarily reach the land surface.
BACK SWAMP DEPOSITS:	Thin layers of silt and clay deposited in the flood basin behind the natural levees of a river or distributary.
BEDDING PLANE:	The division plane in sedimentary or stratified rocks which separates the individual layers, beds, or strata.

BEDROCK:	Any solid rock exposed at the surface or overlain by unconsolidated materials.
BIOTITE:	A generally black, dark brown, or dark green rock forming mineral of the mica group: $K(Mg, Fe^{+2})_3 (Al, Fe^{+3})Si_3O_{10}(OH)_2$.
CALCITE:	A common, usually white, rock forming mineral consisting of calcium carbonate ($CaCO_3$)
CAPILLARY FRINGE:	The zone of partial or complete saturation directly above the water table in which water is held in the pore spaces by capillarity.
CATACLASTIC TEXTURE:	A texture in a dynamically metamorphosed rock produced by severe mechanical crushing and differential movement of the component grains and characterized by granular, fragmentary, deformed, or strained mineral crystals flattened in a direction at right angles to the mechanical stress.
CEMENT:	Chemically precipitated mineral material that occurs in spaces among the individual grains of a consolidated sedimentary rock, thereby binding the grains together as a rigid, coherent mass.
CHANNEL DEPOSITS:	An alluvial deposit in a stream channel, especially, one in an abandoned cutoff channel or where the transporting capacity of the stream is insufficient to remove material supplied to it.
CLASTIC ROCK:	A consolidated sedimentary rock composed of broken fragments that are derived from pre-existing rocks, e.g. sandstone, conglomerate, or shale, etc.
CLAY:	A rock or mineral fragment or a detrital particle of any composition often a crystalline fragment of a clay mineral, smaller than silt having a diameter of less than 1/256 mm.
COLIFORM:	Designating, of, or like the aerobic bacillus normally found in the colon.
CONE OF DEPRESSION:	A depression in the potentiometric surface of a body of groundwater that has the shape of an inverted cone and develops around a well from which water is being withdrawn. It defines the area of influence of a well.

CONFINING BED: A bed which overlies or underlies an aquifer and which, because of low permeability relative to the aquifer, prevents or impedes upward or downward loss of water and pressure. An aquitard or aquiclude.

CONFINED WATER: Water under artesian pressure. Water that is not confined is said to be under water table conditions.

CONSOLIDATED: A rock that is firm and rigid in nature due to the natural interlocking and/or cementation of its mineral grain components. The reverse is unconsolidated.

CONTOUR (Topographic): An imaginary line or surface along which a certain quantity, otherwise varible, has the same value, e.g. an elevation line, structure contour.

CROSS-SECTION: A diagram or drawing that shows features transsected by a given plan; e.g. geologic features such as geologic structure.

DARCY: A standard unit of permeability, equivalent to the passage of one cubic centimeter of fluid of one centipoise viscosity flowing in one second under a pressure differential of one atmosphere through a porous medium having an area of cross-section of one square centimeter and a length of one centimeter.

DELTA: The low, generally triangular shaped, nearly flat, alluvial tract of land deposited at or near the mouth of a river.

DIABASE DIKE: A tabular igneous intrusion made of labradorite and pyroxene that cuts across the planar structures of the surrounding rock.

DIP: The maximum angle at which a rock bed is inclined from the horizontal.

DISTRIBUTARY: An irregular, divergent stream flowing away from the main stream and not returning to it, as in a delta or on an alluvial plain.

DRAWDOWN: The depression of decline of water level in a pumped well or in nearby wells caused by pumping. It is the vertical distance between the static and the pumping levels of the well.

EROSIONAL UNCONFORMITY:	An unconformity made manifest by erosion, or a surface that separates older rocks that have been subjected to erosion from younger sediments that cover them.
ESTAURINE DEPOSITS:	A sedimentary deposit laid down in the seaward end or the widened funnel-shaped tidal mouth of a river valley where freshwater mixes with and measurably dilutes seawater and where tidal effects are evident.
EUTECTONIC:	Gradual structural movements in the earth's crust noted by broad uplifting or subsidence in a region.
EVAPOTRANSPIRATION:	The combined discharge of water to the air by direct evaporation and plant transpiration.
FAULT:	A fracture or fracture zone along which there has been movement of two rock masses relative to one another parallel to the fracture. The movement may be a few inches or many miles.
FLOOD PLAIN:	The strip of relatively-smooth land adjacent to a river channel and built of alluvium carried by the river during floods. The flood plain is covered by water when the river is in flood.
FLUVIAL:	Of or pertaining to a river or rivers.
FOLIATION:	A general term for a planar arrangement of textural or structural features in any type of rock.
FORMATION:	A field-recognizable unit of geologic mapping consisting of a large stratum of some one kind of rock or a recognizable sequence of rocks.
GEOHYDROLOGY:	Referring to the hydrologic or flow characteristics of subsurface waters in relationship to geology. (syn: groundwater hydrology)
GLAUCONITE:	A dull green, amorphous, and earthy or granular mineral of the mica group: $(K, Na)(Al, Fe^{+3}, Mg)_2(Al, Si)_4O_{10}(OH)_2$.
GNEISS:	A foliated rock formed by regional metamorphism in which bands or lenticles of granular minerals alternate with bands and lenticles in which minerals having flaky or elongate prismatic habits predominate.

GPD:	Gallons per day.
GRAVEL:	An unconsolidated, natural accumulation of rounded rock fragments with a diameter greater than 2 mm.
GROUNDWATER:	Water beneath land surface in the zone of saturation and below the water table.
HORNBLENDE:	The commonest mineral of the amphibole group: $Ca_2Na(Mg, Fe^{+2})_4(Al, Fe^{+3}, Ti)(Al, Si)_8 O_{22}(O, OH)_2$.
HYDRAULIC CONDUCTIVITY:	The permeability coefficient; the rate of flow of water in gallons per day through a cross section of one square foot under a unit hydraulic gradient, at the prevailing temperature or adjusted for a temperature of 60°F.
HYDRAULIC GRADIENT:	In an aquifer, the rate of change of pressure head per unit of distance of flow at a given point in a given direction.
HYDROGEOLOGY:	The science that deals with subsurface waters and related geologic aspects of surface waters.
HYDROLOGY:	The science that studies the waters of the earth.
HYDROSTATIC HEAD:	The height of a vertical column of water,the weight of which, if of unit cross section, is equal to the hydrostatic pressure at a point; static head as applied to water.
INFILTRATION:	The flow or movement of water into the subsurface soil and rocks.
IGNEOUS ROCKS: (Basement Rock)	Rocks formed by the cooling and crystallization of molten or partly molten material.
IMPERMEABLE:	Having a texture which does not allow perceptible movement of water through rock.
INTERSTICES:	The openings or pore spaces in a soil or rock formation. In an aquifer, they are filled with water.
INTRUSIVE:	Refers to igneous rocks which have penetrated into or between older rocks while molten but have solidified before reaching the surface.

ION:	An electrically charged atom or group of atoms.
LEVEE DEPOSITS:	A stream deposited enbankment along a river or watercourse.
MARL:	A general term for unconsolidated deposits composed of clay and calcium carbonate.
METAMORPHIC ROCKS:	Any rock derived from pre-existing rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth within the earth's crust.
METAVOLCANICS:	Metamorphosed volcanic rocks.
MUSCOVITE:	A mineral of the mica group: $KAl_2(Al, Si_3)O_{10}(OH)_2$.
NONFLOWING ARTESIAN WELL:	An artesian well in which the head is not sufficient to raise water to the land surface at the well site.
NORMAL FAULT:	A fault in which the hanging wall appears to have moved downward relative to the footwall.
OROGENIC:	Pertaining to the process of formation of mountains.
PERCOLATION:	Movement of water through the interstices of rocks or soils except movement through large openings such as solution channels.
PERMEABILITY:	The ability of a rock to transmit water per unit of cross-section.
POINT BAR DEPOSITS:	Series of low, arcuate ridges of sand and gravel developed on the inside of a growing meander by the slow addition of individual accretions accompanying migration of the channel toward the outer bank.
POROSITY:	The ratio of the volume of the openings in a rock to the total volume of the rock.
POTENTIOMETRIC SURFACE:	An imaginary surface representing the static head of groundwater and defined by the level to which water will rise in a well.

PROGRADATIONAL DELTA: A delta built forward or outward toward the sea by river deposition.

RECHARGE: The addition of water to an aquifer by natural infiltration or artificial means.

REGRESSIVE: Said of deposits laid down during the retreat or contraction of the sea from land areas.

ROCK: Any naturally formed, consolidated, or unconsolidated material (but not soil) composed of two or more minerals, or occasionally of one mineral, and having some degree of chemical and mineralogic constancy.

RUNOFF: That part of precipitation that appears in surface streams.

SAND: A rock fragment ranging in diameter from 1/16 to 2mm.

SCHIST: A strongly foliated crystalline rock formed by dynamic metamorphism.

SEDIMENT: Solid, fragmental, weathered rock material born and deposited by water.

SEDIMENTARY ROCKS: Usually-stratified formations consisting of products of weathering by action of water, wind, ice, etc. (i.e., sand, sandstone, clay, shale, etc.)

SILT: A rock fragment or detrital particle ranging in diameter from 1/256 to 1/16 mm.

SPECIFIC CAPACITY: The rate of discharge of a water well per unit of drawdown commonly expressed in gallons per minute per foot.

STATIC WATER LEVEL: That water level of a well that is not being affected by withdrawal of groundwater.

STRUCTURE: The general disposition, attitude, arrangement, or relative positions of the rock masses of a region or area, also referred to as "structural geology".

TERRACE DEPOSITS: Deposits of alluvium (clay, silt, sand, gravel, or cobbles) which occur along the margin and above the level of a body of water, marking a former water level.

TERRIGENOUS:	Land derived.
TOPOGRAPHY:	The relief and form of a land surface.
TRANSGRESSIVE:	Deposits laid down during the advance or extension of the sea over land areas.
TRANSPIRATION:	The process by which water absorbed by plants, usually through the roots, is evaporated into the atmosphere from the plant surface.
TRANSMISSIVITY:	In an aquifer, the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width under a unit hydraulic gradient.
UNCONFINED AQUIFER:	Water not under artesian pressure. Generally applied to denote water below the water table.
UNCONSOLIDATED:	A sediment that is loosely arranged or unstratified, or whose particles are not cemented together.
VAN DER WAALS' FORCES:	Weak attractive forces between electrically neutral atoms and molecules.
WATER WELL:	A man-made excavation that allows the extraction of water from the zone of saturation or that yields useful supplies of water. The well may be drilled, dug, excavated, or jetted.
WATER TABLE:	The surface between the zone of saturation and the zone of aeration; that surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.

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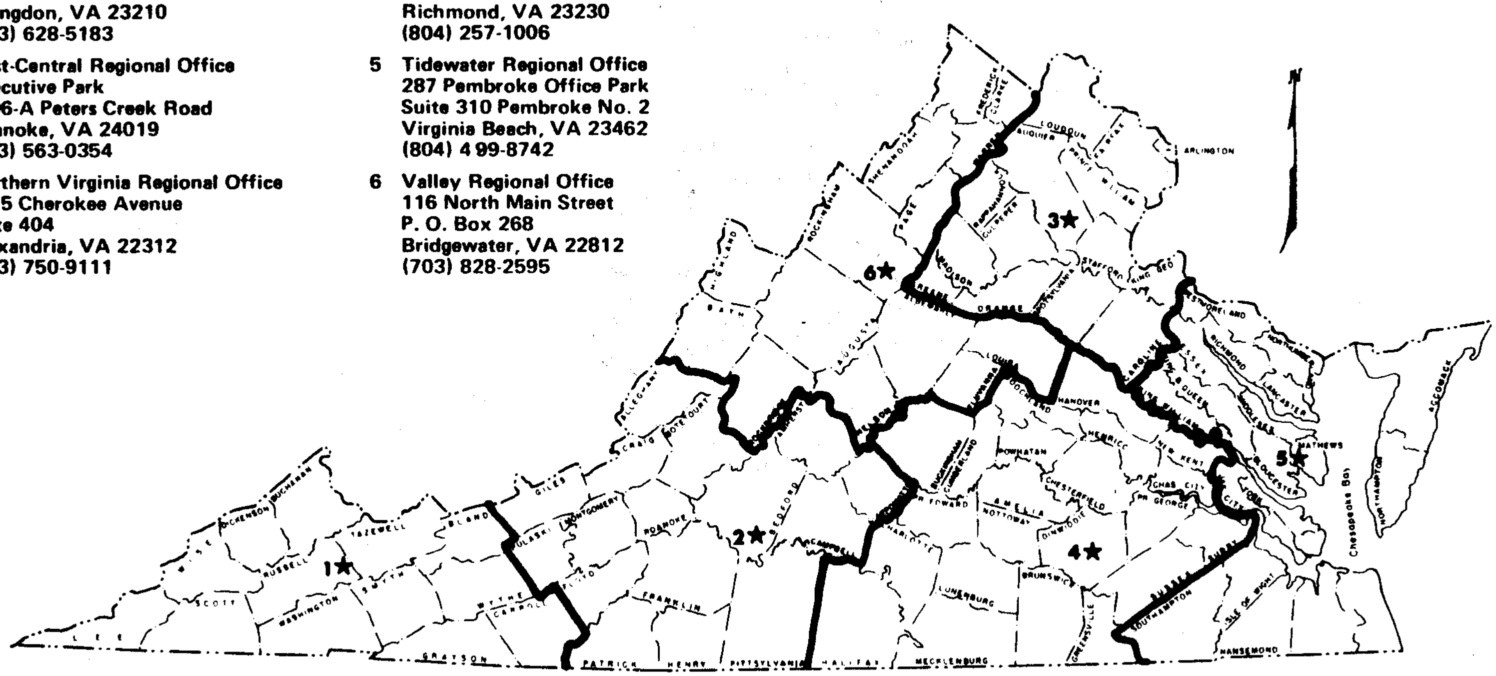

Source: Virginia State Water Control Board

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